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PILOT WATERSHED STUDY
SOIL AND WATER ENVIRONMENTAL ENHANCEMENT PROGRAM

REPORT #6: EVALUATION OF CONSERVATION SYSTEMS, WATER QUALITY

Volume 1: Main Text

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TABLE OF CONTENTS

		Page
EXECUTIVE SUMMARY		
1.0	INTRODUCTION	1.1
1.1	Background	1.1
1.2	Objectives of the Pilot Watershed Study	1.3
1.3	Report Structure	1.5
1.4	Specific Objectives	1.6
2.0	MONITORING INSTALLATIONS AND METHODS	2.1
2.1	Watershed Outlets	2.1
2.2	Microbasins	2.3
2.3	Rainfall Simulation	2.5
2.4	Water Quality Parameter Loading Estimation	2.7
2.5	Groundwater	2.9
3.0	OBSERVATIONS	3.1
3.1	Watershed Scale	3.1
3.1.1	Water Quality Data	3.2
3.1.2	Statistical Summary of Water Quality Data	3.2
3.1.3	Quality Assurance/Quality Control	3.6
3.1.4	Loading Estimates	3.7
3.1.4.1	Loading Estimate Curve Fitting	3.8
3.1.4.2	Loading Estimates	3.9
3.1.5	Effect of Cover on Watershed Loads	3.15
3.2	Microbasin Scale	3.17
3.2.1	Background	3.17
3.2.2	Water Quality Chemistry	3.18

		Page
3.2.3	Microbasin Loads	3.19
3.3	Rainfall Simulation	3.22
3.4	Groundwater Chemistry	3.31
4.0	DISCUSSION AND CONCLUSIONS	4.1
4.1	Discussion	4.1
4.1.1	Watershed Scale	4.1
4.1.2	Microbasin Scale	4.6
4.1.3	Plot Scale	4.7
4.2	Conclusions	4.9
4.2.1	Watershed Scale	4.9
4.2.2	Microbasin Scale	4.10
4.2.3	Plot Scale	4.11
5.0	REFERENCES	5.1

APPENDIX A: Watershed Scale Water Quality Data

APPENDIX B: Water Quality Loading Estimates

APPENDIX C: Microbasin Scale Water Quality Data

APPENDIX D: Rainfall Simulation Data

APPENDIX E: Groundwater Chemistry

LIST OF TABLES

Table 2.1: Schedule of Environmental Monitoring Station Installations (1988 to 1992)
Table 2.2: Summary of Water Quality Sampling Activity
Table 2.3: Microbasin Flow Monitoring Installations
Table 2.4: Number of Microbasin Events by Year
Table 2.5: Season and Tillage Conditions During Rainfall Simulation Runs
Table 3.1: Average and Mean Total Suspended Solids Concentrations (mg/L) - SWEEP PWS Watersheds
Table 3.2: Average and Median Total Phosphorus Concentrations (mg/L) - SWEEP PWS Watersheds
Table 3.3: Average and Median Filtered Reactive Phosphorus Concentrations (mg/L) - SWEEP PWS Watersheds
Table 3.4: Summary of Regression Analysis Comparing Automated ISCO Sample Concentrations and Manually Collected Sample Concentrations
Table 3.5: Summary of 1989 to 1992 Total Suspended Solids Loadings
Table 3.6: Summary of 1989 to 1992 Total Phosphorus Loadings
Table 3.7: Summary of 1989 to 1992 Filtered Reactive Phosphorus Loadings
Table 3.8: Generalized PWS Cover (% Live and Dead) Patterns by Month and Crop-Tillage System
Table 3.9: Watershed Scale Average Cover (% Live & Dead) by Season
Table 3.10: Regression Analysis Coefficients Relating Watershed Loads to Flow and Percent Cover
Table 3.11: Summary of Average and Median Microbasin TSS Concentrations
Table 3.12: Summary of Average and Median Microbasin TP Concentrations
Table 3.13: Number of Microbasin Events by Year
Table 3.14: Selected Essex Microbasin Unit Area Flow and Load Events
Table 3.15: Selected Kettle Creek Microbasin Unit Area Flow and Load Events
Table 3.16: Selected Pittock Microbasin Unit Area Flow and Load Events
Table 3.17: Characteristics of Rainfall Simulation Sites
Table 3.18: Summary of Rainfall Simulation Results, Total Suspended Solids Loads
Table 3.19: Summary of Rainfall Simulation Results, Total Phosphorus Loads
Table 3.20: Groundwater Total Phosphorus Concentration
Table 3.21: Groundwater Total Phosphorus Concentrations (1989-1992)

LIST OF FIGURES

Figure 1.1: SWEEP Organizational Structure
Figure 1.2: Sweep PWS Watersheds in Southern Ontario
Figure 2.1: Essex Sub-Watersheds
Figure 2.2: Kettle Creek Sub-Watersheds
Figure 2.3: Pittock Sub-Watersheds
Figure 2.4: Essex Control Sub-Watershed
Figure 2.5: Essex Test Sub-Watershed
Figure 2.6: Kettle Test Sub-Watershed
Figure 2.7: Kettle Control Sub-Watershed
Figure 2.8: Pittock Control Sub-Watershed
Figure 2.9: Pittock Test Sub-Watershed
Figure 3.1: Essex TSS Loadings
Figure 3.2: Kettle Creek TSS Loadings
Figure 3.3: Pittock TSS Loadings
Figure 3.4: Essex TP Loadings
Figure 3.5: Kettle Creek TP Loadings
Figure 3.6: Pittock TP Loadings
Figure 3.7: Essex TSS Unit Area Loadings
Figure 3.8: Kettle Creek TSS Unit Area Loadings
Figure 3.9: Pittock TSS Unit Area Loadings
Figure 3.10: Essex TP Unit Area Loadings
Figure 3.11: Kettle Creek TP Unit Area Loadings
Figure 3.12: Pittock TP Unit Area Loadings
Figure 3.13: Essex TSS Unit Area Loadings
Figure 3.14: Essex TP Unit Area Loadings
Figure 3.15: Kettle Creek TSS Unit Area Loadings
Figure 3.16: Kettle Creek TP Unit Area Loadings
Figure 3.17: Pittock TSS Unit Area Loadings
Figure 3.18: Pittock TP Unit Area Loadings
Figure 3.19: Essex Microbasin TSS Load vs. Flow
Figure 3.20: Essex Microbasin TP Load vs. Flow
Figure 3.21: Kettle Creek Microbasin TSS Load vs. Flow
Figure 3.22: Kettle Creek Microbasin TP Load vs. Flow
Figure 3.23: Rainfall Simulation Summary Total Suspended Solids
Figure 3.24: Rainfall Simulation Summary Total Phosphorus

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1.0 INTRODUCTION

1.1 Background

The Soil and Water Environmental Enhancement Program (SWEEP) was initiated in 1986 with an overall mandate to:

- reduce Ontario's Non-Point Source (NPS) loadings of phosphorus to Lake Erie from agricultural sources by 200 tonnes; and

- maintain or improve the productivity of the primary agricultural sector in Southwestern Ontario by reducing or correcting soil erosion and degradation.

The Pilot Watershed Study (PWS) is a major SWEEP sub-program aimed at evaluating and demonstrating the benefits of established conservation farming systems at the watershed and smaller scales. Figure 1.1 shows the overall SWEEP organizational structure and the PWS sub-program relationship to the Program. Cooperating agencies; Environment Canada (EC), Agriculture Canada (AC), and the Ontario Ministry of the Environment (MOE) are identified. Beak Consultants Limited (BEAK) is the prime contractor responsible to AC and MOE. Ecologistics Limited (ECOLOGISTICS) is a sub-contractor to BEAK responsible for site selection and the agronomic program of the PWS.

The PWS started in 1987 with detailed study design, staffing, training, cooperator enlistment, and watershed selection. Farm plans were initiated in August, 1988 and environmental monitoring began later the same year.

Monitoring and evaluation were conducted from late 1988 until mid 1992.

Figure 1.2 shows the location of PWS subject areas within the Lake Erie Watershed. These are situated within different yet common agricultural and physical settings.

The PWS has the following key features:

- four year implementation and monitoring period;
- **test** (conservation oriented systems) and **control** (conventional systems) paired watershed design;
- pro-active agronomic management involving annual farm planning, cooperator compensation program, ongoing producer extension program, availability of conservation-type farm implements, detailed cooperator record keeping, crop scouting and productivity analysis, and farm level socio-economic evaluation;
- intensive and continuous environmental monitoring at plot, field and watershed scales;
- detailed soil survey and soil quality monitoring;
- extensive environmental monitoring program including meteorology, hydrology and water quality; and
- detailed evaluation involving the application of two modelling systems for farm planning and systems evaluation.

The paired watershed study design is a unique approach which relies upon direct comparisons between the **test** and **control** areas as the primary method of environmental and agronomic evaluation. The effects of scale, at whole watershed, farm, field and plot scales are also a fundamental aspect of the study design which systematically addresses the relationship between producer attitudes and adoption as well as between measurable benefits, complexity, and scale.

1.2 Objectives of the Pilot Watershed Study

Objective Regarding Study/Approach

To achieve a high level of adoption of the most appropriate soil and water conservation practices among farm operators utilizing lands in the **test** sub-watersheds.

Strategy

1. Develop and employ a watershed selection process which:

   a) optimizes the probability of farm operator adoption of desirable practices, and
   b) can be applied effectively to critical areas in the larger Lake Erie basin.

2. Develop and utilize improved soil and water conservation planning tools for application at the farm and watershed levels.

3. Develop and utilize contract arrangements with cooperating farm operators which specify and compensate for participation in the project without "buying" their participation.

Objective Regarding Effectiveness

To determine the nature and degree of changes in relevant soil and water quality parameters and crop yields as influenced by "basin-wide" soil and water conservation practices.

Strategy

1. Select pairs of watersheds which are as similar as possible in respect to physiography, hydrology, and farming systems.

2. Develop and apply mechanisms to encourage adoption of soil and water conservation practices throughout the life of the project in the **test** sub-watersheds and to discourage adoption in the **control** sub-watersheds.

3. Establish soil, water and crop yield baseline conditions and monitor changes in relevant parameters throughout the life of the sub-program.

4. Correlate changes in soil, water and crop yield parameters to soil and water conservation practices and systems.

5. Evaluate improvements to planning tools (models) achieved during the sub-program.

6. Evaluate factors that affect the adoption of soil and water conservation practices and that influence farmer attitudes towards both the practices and the goals of the sub-program.

Objective Regarding Information Dissemination

To prepare information about sub-program activities and results and to transmit this to participating farmers and other related SWEEP sub-programs.

Strategy

1. Collect and transmit, as required, to the SWEEP sub-program contractor responsible for the farm-level and basin-wide economic analysis.

2. Prepare information on activities and results for the communications sub-program contractor.

3. Prepare periodic reports to cooperating farmers on activities and results in written and meeting formats.

1.3 Report Structure

The overall PWS reporting has been sub-divided into the following categories:

- Report #1 - Study Area Selection, Description and Climate
- Report #2 - Implementation of Conservation Systems
- Report #3 - Evaluation of Conservation Systems, Attitudinal
- Report #4 - Evaluation of Conservation Systems, Soils and Crops
- Report #5 - Evaluation of Conservation Systems, Hydrology
- Report #6 - Evaluation of Conservation Systems, Water Quality
- Report #7 - Modelling
- Report #8 - Executive Summary

Each report is a stand alone document including a summary, descriptions of objectives, methodologies, observations, discussion, and summarized listings of relevant data where applicable. The Executive Summary is a compilation of summaries from all of the technical reports.

This report documents the study area selection process which occurred between late 1987 and mid 1988; the social, environmental and agronomic characteristics of the subject watersheds as evident during the selection process; and the weather conditions in effect during the monitoring period from the start of 1989 to mid 1992.

1.4 Specific Objectives

The component of the study documented in this report has the following objectives:

- through environmental monitoring, quantify the loading rates of phosphorus and the rates of soil loss in the short (event) and long (seasonal) term at three scales (i.e., watershed, field and plot);

- investigate the relationships between farm-soil conservation systems implementation and material transport rates at three scales in the short (event) and long (seasonal) term; and

- quantify and summarize the benefits to receiving waters of conservation systems adoption at the watershed scale.

2.0 MONITORING INSTALLATIONS AND METHODS

The program for water quality monitoring of the PWS has been designed in conjunction with the water quantity monitoring program to meet the environmental runoff data requirements of the evaluation program. This requires that sufficient water quality data be compiled at whole watershed scales and microbasin scales to allow for the estimation of event, seasonal and annual mass loadings of sediment and phosphorus.

2.1 Watershed Outlets

Installations

The Ontario Ministry of the Environment has installed automatic sequential water samplers (ISCO model #2700) in each of the WSC shelters at the six sub-watershed outlets. The locations of these stations are identified in Figures 2.1 to 2.3. The WSC shelters are heated, thus allowing for year-round operation. At each site the sampler's 3/8" vinyl line was pulled through a rigid plastic conduit which extends from the walk-in shelter to the drain. The sampling lines are all self-draining and so protection against freezing is unnecessary. Of course, the sampler lines will freeze at the drain but automatic sampling will be unnecessary at times when the drain water is frozen. Sampler lines usually thaw rapidly and become clear of ice when winter runoff events occur. Some freezing at the Kettle Creek site has caused the loss of samples. Ponding at these areas has resulted in the development of an ice block which does not melt quickly. Table 2.1 identifies the installation dates for water samples in each shelter.

Operation

The sampling system has been designed to collect runoff event samples at each sub-watershed mouth during at least ten representative events per year, distributed over the spring snowmelt, late spring, summer and fall runoff periods.

When a runoff event was anticipated, the watershed technician programmed the samplers to collect samples hourly. The samplers collected 24, 1 litre samples over a period of 24 hours. Full sample bottles were recovered and replaced with clean bottles when full. This routine was continued until the runoff event had ended. A representative subset of samples was taken from the field set at the end of the event based upon observed water levels. All selected samples were field filtered and sub-divided into a filtered and an unfiltered aliquot for analysis at the MOE laboratory in London.

Interevent samples were collected by grab sampling directly from the drain on a monthly basis. Interevent samples were field filtered and handled in the same manner as runoff samples.

This frequency of sampling was sufficient to generate reliable correlations between flow rate and water quality concentrations for suspended solids, total phosphorus, and filtered reactive phosphorus on a seasonal basis and thereby to generate a predicted time series of water quality concentrations and loads to accompany the continuous flow records. The multiplication of flow rate and water quality concentration yields loading, which is the main management parameter of concern.

Samples were submitted by the PWS technician to the MOE London Laboratory for analysis of eleven water quality parameters including:

- total suspended solids (TSS),
- ammonia (NH_3),
- total Kjeldahl nitrogen (TKN),
- nitrite nitrogen (NO_2),
- nitrate nitrogen (NO_3),
- total phosphorus (TP),
- filtered reactive phosphorus (FRP),

- pH,
- chloride,
- potassium (K), and
- conductivity.

All samples were handled according to MOE protocols. Samples were kept cool (4°C) and were delivered to the London laboratory within 72 hours of collection. Table 2.2 lists the number of events and interevent periods samples by season in each sub-watershed pair during the course of the study.

A quality assurance/quality control (QA/QC) program was established at the onset of the water quality monitoring phase of the SWEEP PWS. The purpose of the QA/QC program was twofold:

- to obtain a measure of variability in automated ISCO samples versus manually collected; and
- adjust the ISCO sampler intake appropriately if deemed necessary.

The goal of the QA/QC program was to collect duplicate samples during all flow regimes at a 5 to 10% level (1 or 2 sample duplicates for every 20 samples).

2.2 Microbasins

Installation

Microbasin monitoring stations have been set up at sites which provide adequate hydraulic control for surface runoff (Figures 2.1 to 2.3). These stations have been selected so that surface runoff only is monitored and all of the surface runoff from a microbasin is collected. That is, there are no tile drain outfalls or drop inlets upstream of these sites.

Table 2.3 provides a description of each microbasin installation, as they differ in several respects. Flow recording instruments are protected at each site (except ETB2 and ECB1) by locking covers set atop stilling wells (except KCB2 which has a weir box). Stilling wells are connected hydraulically to just upstream of the V-notches with a buried steel pipe. Stilling wells are made from 0.3 m diameter galvanized steel culverts. The V-notch weirs are made of aluminum and are fastened to a wooden frame built around the upstream end of the culverts. At KCB2 there is a weir box which captures flow from the road culvert, provides some stilling and discharges through a V-notch. Stations ETB2 and ECB2 have Parshall flumes set into road ditches. Water levels are measured in small stilling wells attached to the flumes.

Operation

Water quality samples were taken during storm events at each microbasin by manual grab sampling or by using programmed automatic sequential samplers (ISCO models 2100 and 2700).

The PWS technicians collected from 2 to 10 samples per site per event in order to provide for a rigorous analysis of event loadings.

All samples were kept cold (4°C) until delivery to the BEAK analytical laboratory for analysis of total suspended solids and total phosphorus.

Microbasin sites were frequently cleared of weeds and debris to ensure trouble-free operation.

Table 2.4 lists the number of microbasin events sampled by year for each microbasin.

2.3 Rainfall Simulation

In this study, micro scale research was carried out using a portable rainfall simulator developed by Tossell *et al.* (1987) at the University of Guelph. This system provides a relatively uniform simulated rainstorm on plots measuring 1 m x 1 m. Sampling sites were located on a midslope position in each of the six sub-watersheds in the PWS. Three replicate plots were measured at each sampling site. The sites were chosen based on the cropping and tillage practices within the field. Sites on the **control** sub-watersheds were established on fields where conventional tillage practices (fall moldboard plowing) occurred. **Test** sites were established on sites with the same crop but with a conservation management practice. In all cases, attempts were made to select sites with similar soils and slopes but the most important factor in site selection was crop due to the strong effect of residue on runoff and water quality stated in the literature. Due to differing crop rotations, the same sites were not always used throughout the study but in all cases, the crop was a consistent factor at least within each sub-watershed pair.

Simulations were carried out a total of five times in attempts to determine if any seasonal effect on water quality existed. Rather than the actual date, the condition of the soil in terms of tillage operation was used to determine the "seasons" of measurement. Each time, replicated runs were performed on the **test** and **control** sites on the same day. The only exception was in the fall of 1991 when runs were carried out only once on the Kettle Creek and Pittock test sites. Since no tillage or other activities were to occur in the **test** fields after harvest, the results obtained on these sites for post harvest 1991 were used to compare with the **control** sites for post harveset 1991 and post fall tillage 1991. Care was taken to ensure that soil conditions for the post fall tillage 1991 runs at Kettle Creek and Pittock were similar to those of the post harvest 1991 runs in terms of soil moisture. Table 2.5 provides a list of the times of measurement and the identification codes that will be used throughout the remainder of this discussion.

The plots were set up as described in Wall *et al.* (1990). Prior to the onset of simulated rainfall, several measurements including moisture content, slope and residue cover were taken. Moisture content was determined by taking small soil samples just outside the four corners of each plot, placing them in a plastic bag and determining their gravimetric moisture content in the laboratory (Klute, 1986). Slope was calculated as the difference in distance (cm) from the soil to a level meter stick from the top of the plot to the lip at the bottom end on each side of the plot. Residue cover was determined using the knotted rope method. Here, a 1 m long string was knotted every 4 cm for a total of 25 knots along the string. The string was laid across the soil surface within the plot perpendicular to the direction of the crop row 4 times. The presence of a piece of crop residue (dead and alive) under a knot was noted. A total of 100 knots were examined and consequently, the sum of knots touching crop residue was taken as the percent cover for that plot.

Once the initial measurements were made, rainfall simulation commenced. An intense rainfall was used to simulate the worst case scenario. The use of the 1.27 cm nozzle (1/2 inch), 1.5 m from the ground surface, simulating rainfall for a period of 10 minutes at an intensity of 2.67 mm/min resulted in a total rainfall of 2.67 cm (26.7 litres). The return period of such a storm is approximately 50 years.

Once runoff began, the volume collected was noted every minute until the end of the run. After ten minutes, the total runoff collected plus that remaining in the collection trough were totalled to obtain a total runoff volume for that run. At the end of each simulation run, the runoff was stirred vigorously to evenly distribute the sediment in the sample. While the water was still in motion, a 500 mL aliquot was removed and stored in a plastic container. The remaining runoff was discarded and the aliquot was analyzed for total suspended solids and total phosphorus concentrations at BEAK's analytical laboratory (Beak Analytical Services). Using the concentration data and the runoff volume, total load estimates were made.

Hydrological parameters measured such as total runoff volume, time to ponding and time to runoff are discussed in the hydrology section of this report.

Data was analyzed statistically using t-tests for **test** and **control** pair comparisons and ANOVA's for multi-factor comparisons. Duncan's Multiple Range test was used to identify significantly different values.

2.4 Water Quality Parameter Loading Estimation

During the SWEEP study, both water quality and streamflow data were collected for the purpose of computing water quality loadings from the sub-watersheds. Streamflow was collected on a continuous basis, while water quality samples were collected during critical periods such as event and baseflow periods. This type of flow and water sampling scheme has been used extensively for water quality monitoring studies similar to this study (BEAK, 1989). Due to these sampling methods, a continuous record of observed water quality parameter chemistry is not possible or practical. The water quality parameter loadings have been estimated using statistical correlations between the continuous flow and discontinuous water chemistry data.

In the absence of a continuous record of water quality chemistry, a water quality predictive loading model was developed to facilitate the computation of continuous water quality loadings. The model is known as the Sweep Loads Model (SLM) (BEAK, 1989).

The loading model used a least squares technique was used to determine the **best fit** or best relationship between water quality parameters and streamflow. This approach is similar to the **rating curve** procedure to estimate transport or loading rates (Linsley and Franzini, 1979; Overton and Meadows, 1976; Walling, 1977; Schroeter and Watt, 1989). The rating curve consists of a graph or equation, relating mass discharge or concentration to discharge, which can be used to estimate water quality parameter loads from the continuous streamflow record.

This approach is analogous to the stage-discharge curves used to establish streamflows at gauging stations.

Discrete values of the loads were computed using:

$$L_i = C_i\ Q_i \qquad [2.1]$$

where L_i is the instantaneous load or transport rate (M/T) for water quality sample i, C_i is the measured concentration (M/L^3) and Q_i is the observed instantaneous flow (L^3/T) corresponding to sample i. For a few samples, the observed flow (Q_i), has been reported as zero, when in fact there was actually a small flow (less than 1.0 L/s). In these cases, the sample flow Q_i used to compute the load L_i for the purpose of fitting Eq. [4.1] has been assigned a value of 0.0005 m^3/s, which is half the value of the lowest flow reported by the Water Survey of Canada. The equation used for the computation of PWS water quality loadings was in the form of the power equation below:

$$L_p,\ C_p = aQ^b \qquad [2.2]$$

where: L_p = Load of a water quality parameter p, (M/T);

C_p = concentration of a water quality parameter p, (M/L^3);

Q = flow discharge at the water quality sampling station, (L^3/T);

a and b are regression determined coefficients.

Water quality and streamflow information are rarely normally distributed due to the frequency at which flow events occur (i.e. high flows are rare while low flows are common). Statistical procedures such as least squares regression are based on the fundamental premise that the data are normally distributed about the mean. Logarithmic transformations were applied to the discrete values of L and Q, to normalize the data set and then a standard linear regression technique (Draper and Smith, 1981) was performed to estimate values for **a** and **b** in Eq. [2.1].

When sediment loads are being considered, some workers have referred to the coefficient **a** as an **erodibility** factor (Linsley and Franzini, 1979; Overton and Meadows, 1976). In general, the rating curve approach has seen wide application for estimating sediment discharge (Walling, 1977), although Betson and McMaster (1975) demonstrate its use for dissolved mineral constituents, and Verhoff *et al.* (1980) for nutrient transport rates.

This type of water quality loading estimation results in a separate and discrete regression equation for each year or portion of year. Furthermore, through this type of analysis, yearly or seasonal coefficients can be compared to evaluate or to correlate with other variables (i.e., rainfall, effectiveness of cover plant residue, etc.). Coefficients from Equation 2.2 were estimated for each year in these parts; January to April (non-growing season), May to October (growing season) and November to December (non-growing season) to produce water quality loads and concentrations for the following parameters:

- Total Suspended Solids (TSS),
- Total Phosphorus (TP), and
- Filtered Reactive Phosphorus (FRP).

The result was a continuous time series record of water quality loadings for each of the above mentioned seasons and years. Water quality loadings were computed on an hourly basis and can be summarized into various standard periods such as daily, monthly and yearly summaries. The three seasonal periods used respect differences in live cover, soil moisture, and freezing conditions over the year.

2.5 Groundwater

Groundwater monitoring in the study addressed groundwater levels and quality as a measure of subsurface phosphorus transport potential. Groundwater quality was tracked at two sites in each sub-watershed, twelve in all, near the microbasin installations. This was accomplished

using piezometers and routine groundwater sampling. From December 7 to 14, 1988, piezometers were installed using one and one half inch diameter schedule 40 PVC pipe. A three foot section of slotted screen (0.1 mm openings) was attached to the bottom and a threaded PVC cap to the top of a five foot section of pipe. The pipes were placed in augered holes and backfilled with sand to the depth of the slotted screen. A peltonite seal was backfilled atop the sand to a further depth of about 30 cm. Native soils were used to backfill the top of the excavation. These installations were designed to exclude foreign particulate material and surface seepage. Groundwater piezometers were purged dry several times over the first few months to flush any foreign particulate material. Groundwater samples were extracted using a length of vinyl tubing fitted with a foot valve on one end. The tube was repeatedly raised and lowered until a sufficient sample volume had entered the tubing.

Groundwater samples were submitted to Beak Analytical Services (BAS) in Brampton, unfiltered for total phosphorus analyses.

Figures 2.4 to 2.9 show the sub-watersheds with groundwater piezometer locations.

3.0 OBSERVATIONS

3.1 Watershed Scale

The collection of representative water quality data is paramount for evaluating a land management/environmental program such as the Pilot Watershed Study. The water quality sampling program designed and implemented for the PWS study was extensive producing over 350 discrete water quality samples in each of the six sub-watersheds during the study period of January 1989 to June 1992. These samples were collected during both runoff event and low flow periods. An average of 100 samples per year were collected in each of the Essex paired watersheds; the average number of samples were much higher in the Kettle Creek and Pittock sub-watersheds.

Despite the large number of representative water quality samples collected during this study care must be taken when interpreting results - particulary when comparing water quality loads between study areas and between paired watersheds. There are a number of potential differences or sources of error such as: watershed hydraulic differences, land management variability, climatic variability, measurement error, sample collection error, analytical error, and human error. Other lesser sources of error also exist. The resultant sum of these errors may result in a 10 to 25% (or possibly higher for a given event or season) total error. The end result means that it is very difficult to state definitively that differences in water quality parameter concentrations and loadings exist if the differences at the watershed scale are less than the estimated error. Nonetheless, analysis of the effects of land management on water quality can be achieved through trend analysis extending over several years (six to ten) of monitoring (NWQEP, 1992).

One of the many factors that must be kept in mind while conducting this type of land management/water quality study is that it takes time for benefits of the sum of the land conservation practices to equilibrate and improve soil and runoff water quality. In addition,

in some cases many of the most beneficial farm conservation practices such as no-till systems were not implemented wholesale at the onset of the sub-program in 1988 - rather they were implemented on a small scale in 1990 graduating to a larger degree of implementation in 1992 as farmers became comfortable with the new management systems. The evaluation of water quality benefits documented here represents a period of implementation and is therefore a transition period for the subject areas. On the **test** watershed scale, the geophysical environment was in the early stages of a transition to a new equilibrium induced by gradual conversion to conservation farming systems.

General discussion of water quality concentrations and water quality loadings will focus upon differences and trends over the time period including January 1989 to June 1992.

3.1.1 Water Quality Data

Analytical results of samples collected at the three watersheds are found in Appendix A. The data in Appendix A includes the full set of analytical results for all samples (TSS, ammonia, TKN, nitrate, nitrite, total phosphorus, filtered reactive phosphorus, potassium, chloride, pH, and conductivity). Discussion of water quality parameters will be limited to those upon which the study focuses, namely TSS (a measure of soil loss) and phosphorus.

3.1.2 Statistical Summary of Water Quality Data

Water quality statistics were computed on all sub-watershed data sets for the three main water quality parameters of concern - total suspended solids (TSS), total phosphorus (TP), and filtered reactive phosphorus (FRP). Included in the statistical analysis of water quality concentrations is average or mean, median, standard deviation, maximum, minimum, quartile partitioning data (upper quartile and lower quartile) and coefficient of variation. In addition to yearly statistical summaries, **seasonal** statistical summaries have been produced as well.

Yearly and seasonal statistical summaries of water quality concentrations (TSS, TP, FRP) are found in Appendix A while summaries of yearly and seasonal average and median concentrations are found in Tables 3.1 (TSS), 3.2 (TP) and 3.3 (FRP). Discussion will focus upon the average and median concentrations.

It should also be noted that a few samples in both Pittock and Kettle Creek Watersheds reflect runoff from manure applied lands. For the purposes of conducting statistical summaries these samples have been excluded from the data base. The objective here is to examine the soil and phosphorus losses associated with long-term field activities. However, these samples do show that a significant amount of annual phosphorus loss can originate from manure. The magnitude of phosphorus loadings for manure cannot be addressed with this project and should be the focus of a separate study. The samples excluded from the data base include MA36 to MA39 collected at Kettle Creek **test** sub-watershed on April 29 and 30, 1989; samples HO92 HO94 (November 15-16, 1989) in Kettle Creek **control** sub-watershed; sample WE137A collected on February 9, 1990 in Pittock **control** sub-watershed.

Average and median TSS concentrations for the period of study are highly variable, showing few distinct trends with respect to time or with respect to differences between the **test** and **control** sub-watersheds (refer to Table 3.1). There are, however, some minor trends exhibited in the data set.

In the Essex watershed, the **test** sub-watershed exhibited **higher** annual average TSS concentrations than the **control** sub-watershed in each year except for the first six months of 1992 (refer to Table 3.1). At the same time, average annual TSS concentrations consistently decreased from 1989 to 1992 in Essex **test** whereas TSS concentrations varied from year to year in the **control** sub-watershed. In both of the sub-watersheds in Essex, the period of **April to June** consistently holds the highest seasonal average TSS concentrations.

In the Kettle Creek watershed, the **test** sub-watershed also exhibited **higher** annual average and median TSS concentrations than the **control** sub-watershed except in 1991, although no temporal trends exist (refer to Table 3.1).

In the Pittock watershed, it is the **control** sub-watershed that displays **higher** annual average TSS concentrations compared to the **test** sub-watershed in each year except for the first half of 1992 (refer to Table 3.1). Furthermore, the seasonal average TSS is **higher** in the **control** than the **test** for the periods of **January to March** and **April to June** for each year except 1992. The seasonal median concentration of TSS is also consistently **higher** in the **control** sub-watershed for the period of **January to March**.

In general, Kettle Creek had the highest TSS concentrations on average, closely followed by Essex. Pittock displayed much lower TSS concentrations on average.

Average and median TP concentrations are similar to TSS concentrations in that no trends persist throughout the data with respect to time (refer to Table 3.2), although minor trends do exist.

The Essex **test** watershed exhibits **higher** annual average and median TP concentrations than the **control** sub-watershed in every year except for the first half of 1992 (refer to Table 3.2).

Annual average and median TP concentrations in the Kettle Creek **control** sub-watershed show a consistent increase in each successive year except for 1992 (refer to Table 3.2). Seasonal median TP concentration is consistently **higher** in the **test** sub-watershed for the period of **January to March**.

In the Pittock watershed, the only minor trend exhibited is consistently **higher** seasonal TP concentrations in the **control** sub-watershed for the period of **January to March** (refer to Table 3.2).

As with TSS, Kettle Creek had the highest TP concentrations on average followed by Essex. Pittock had the lowest TP concentrations on average.

Concentrations of FRP exhibit no consistent trends with respect to time (refer to Table 3.3). Minor trends similar to those for TP and TSS do exist.

In the Essex watershed, annual and all seasonal average and median FRP concentrations are **higher** in the **test** watershed except for the first six months of 1992 and the period of July to September (no flow)(refer to Table 3.3).

The Kettle Creek watershed has **higher** annual average and median FRP concentrations in the **control** watershed in every year except the annual average FRP concentrations in 1992 (refer to Table 3.3). Seasonal average and median FRP concentrations are also consistently **higher** in the **control** sub-watershed for the periods of **April to June** and **October to December.**

In the Pittock **test** sub-watershed, annual average FRP stays constant from 1989 to 1990 and then **decreases** in each successive year (refer to Table 3.3). No other minor trends exist.

The portion of total phosphorus which is contained in the FRP fraction varies considerably from one area to another. The FRP fraction represents about 8% of the total phosphorus in Essex, about 16% in Kettle Creek, and almost 35% in Pittock. This is due in part to the fact that FRP concentrations are lowest in Essex, followed by Kettle Creek and highest in Pittock. Clearly, this dissimilarity in phosphorus distribution reflects dissimilar erosional and transport characteristics in the three study areas. Essex and Kettle Creek displayed higher TSS and particulate phosphorus (PP, where PP = TP - FRP) than Pittock. Pittock phosphorus is therefore more likely to be transported as a dissolved constituent, not attached to soil particles as in the other watersheds.

3.1.3 Quality Assurance/Quality Control of the Water Sampling Program

The goal of the water quality assurance/quality control (QA/QC) program was to collect approximately 1 manually collected duplicate QA/QC sample for every 10 to 20 regular ISCO collected samples or a 5 to 10% duplication. This goal was achieved in all watershed pairs. Sample duplication was approximately 10% in both Essex and Pittock sub-watersheds while in Kettle Creek sample duplication was approximately 7%. This level of duplication was more than adequate in assessing the QA/QC program.

Regression analysis was performed on the water quality sample duplicate data to assess the correlation between the automated stream sampling system (ISCO) and manually collected **grab** samples. These linear regressions were performed on total suspended solids (TSS), total phosphorus (TP) and filtered reactive phosphorus (FRP). Results of the regression analysis are illustrated in Table 3.4. Information contained in Table 3.4 includes the number of duplicate sample comparisons (observations), the correlation coefficient (R^2), slope and y-intercept obtained for each parameter in the six sub-watersheds. The purpose of including the slope and intercept information is for completeness. In the ideal case where there is a perfect relationship between the two sampling techniques, the correlation coefficient and slope would equal 1.00 and the intercept would be zero. However, given the natural variability alone, it would be highly unlikely to obtain perfect relationship. Reasonable values would be greater than 0.85 for the correlation coefficient, 1.00±0.1 for the slope and intercept at or near zero.

Results of the regression analysis indicate that duplicate samples compare quite well for both TSS and TP in all watershed pairs. QA/QC regression results for FRP were more variable with only half of the sub-watersheds with good duplication.

The slopes for total suspended solids data range from 0.70 in Pittock **test** to a perfect 1.00 in Kettle Creek **control** sub-watershed. The correlation coefficient (R^2) for TSS were quite good, and range from 0.75 (Essex **control** and Pittock **test**)to as high as 0.95 (Kettle Creek **test**). All intercepts were close to the analytical method detection limit.

Total phosphorus regression analysis indicated that the duplication was very good for all sub-watersheds except for Essex **control**. Slopes ranged from 0.63 in Essex **control** to 1.02 in Kettle Creek **test**. The correlation coefficients were very good and ranged between 0.60 in Essex **control** to 0.97 in Kettle Creek **test** and Pittock **control**.

Examination of the data indicates that much of the data correlates well with a few samples which are outliers (see Appendix A). One sample outlier was eliminated from the Pittock **control** data set for the purpose of regression analysis. This data for this sample was eliminated because it biased the regression results since it represented highest concentrations in the comparison. As the ISCO samplers had operated smoothly, differences in concentrations between automated and hand samples may be a result of difficulties in taking the grab samples at high flow and/or laboratory analytical technique variability. Thus, it is believed that the ISCO automatic sampling system was the optimum method to obtain series of representative stream water samples.

3.1.4 Loading Estimates

As referenced to in Section 2.0, a water quality loading model (SLM) was developed for the purpose of predicting loads for this study. The SLM has the capability of predicting loads for event, daily, monthly, seasonal or yearly time periods. However, because it uses water chemistry data to predict loads along with the flow data, the accuracy of the predictions will increase with an associated increase in the number of water quality estimates and the discretization of the data set. Therefore, seasonal prediction estimates are optimal due to the number of samples collected over these periods. Additionally, land use practices alter water quality loadings and these practices are often best characterized seasonally.

The SLM has the capability of calculating loads in a number of well defined methods including: the rating curve method, flow stratification methods, interpolation, least squares optimization and combined techniques. Following a very thorough examination of loading

methods for predicting loads, it was determined that the rating curve method produced the best loading estimates for the PWS data.

Results of the loading analysis are presented in Appendix B. Due to the nature of the rating curve method for determining loads, the seasonal method for producing loads which were slightly more sensitive to the high flow periods - thus producing more accurate load estimates for the high flow events. This is accomplished simply by partitioning the data into the seasons or periods indicated in the data from Appendix A (January - April, May - October, November - December). If the loads are calculated using yearly periods, the estimates will be more accurate for those events or periods with the most frequent flows (low flow events) because the rating curve method calculates the loads based on most abundant data. The high flow events are less frequent over the full year and thus do not have the same curve fit weighting as do low flow events. When the year is partioned into seasons then separate calculations for each season tend to better reflect the unique conditions at that period.

3.1.4.1 Loading Estimate Curve Fitting

During the calculation of water quality loadings, the load modelling procedure produces the relationship between the flow and load (concentration) as discussed in section 2.4 (equation 2.2). During the curve fitting procedure, coefficient a and coefficient b (exponent) are generated along with the correlation coefficient (R^2). The curve fitting process showed a high degree of correlation between load and flow, as expected, for all three water quality parameters. The computed R^2 values for TSS (Appendix B) ranged from a low of approximately 0.78 to a high of 0.89 depending on year and watershed. The TP results had similar R^2 values ranging from 0.83 to 0.94 while the FRP generally had lower correlation coefficients which ranged from 0.66 to 0.87.

In each case, the fitted values for the rating curve exponent b were within the range of values quoted in the literature (e.g., Walling, 1977; Betson and McMaster, 1975). The exponents for

TSS and TP were similar in value. It is interesting to note that none of the b exponents of the curve fitting procedure were less than 1.0 which was again similar to the findings from the literature.

The rating curves developed here were applied to the observed hourly flow record to produce estimates of the hourly loads to the end of the reporting period June 1992. For days when hourly flow values were not available from the Water Survey of Canada (WSC) (e.g. during ice cover conditions), the WSC estimated daily average flow data were used to augment the flow data base. The daily estimated loads for all sub-watersheds, as presented in Appendix B in tables while seasonal and annual loadings of TSS and TP are presented in histograms.

A comparison of the seasonal loads with the original yearly loads shows that the curve fit is usually slightly better with the new modified seasonal loads method. However low flow loads are very similar regardless of the method. It is only the very high flows where loads between the two methods differ. As a result of this comparison, it can be seen that total study period loads did not differ between the Essex watershed pairs only the distribution over the study period changed (ie. higher proportion during major events using the modified seasonal loads). Kettle Creek did show a change in not only load distribution, but total loads over the study period as well. When employing the modified seasonal method to compute loads, the totals loads were greater by 10 -15 %. This is a direct result of the better estimation of the high flow event loads. In contrast, Pittock had a lower overall R^2 using the seasonal rather than yearly loading estimates. This is due in part to the hydraulic properties and extensive tile drainage in the Pittock watershed pairs.

3.1.4.2 Loading Estimates

Total suspended solids in runoff from sub-watersheds are derived from overland erosion and if present, streambank erosion. While daily, monthly and annual flow are made up of baseflow as well as event related runoff, TSS is highly event related. Baseflow TSS loadings

are very minimal in all sub-watersheds and are composed of small amounts of material which resists settling (fine clay sized particles and low density particles such as organic matter). Event TSS loadings are largely due to rill (gully) and interrill (sheet) erosion processes on the actively managed fields and some erosion of streambank material. Event TSS loadings occur only when precipitation rates exceed the sub-watershed soils' infiltration rate. These infiltration rates vary considerably from field to field, from watershed to watershed, and from event to event.

Seasonal and yearly loadings of total suspended solids, total phosphorus, and filtered reactive phosphorus were estimated for all sub-watershed outlets. The loading summaries are found in Tables 3.5 (TSS), 3.6 (TP) and 3.7 (FRP). Information included in the seasonal loading tables include: total sub-watershed seasonal load, unit area seasonal load, total sub-watershed yearly load and unit area yearly load. Seasons were broken down as Winter (January to March), Spring (April to June), Summer (July to September) and Fall (October to December). Figures 3.1 to 3.6 show the total TSS and TP loadings in cumulative terms for the sub-watersheds. Figures 3.7 to 3.12 represent the corresponding figures for unit area loads of TSS and TP.

Total Suspended Solids

Seasonal total suspended solids loads (Table 3.5) were quite variable from season to season and watershed to watershed. No consistent trends in seasonal loads were found in any watershed except the Kettle Creek **test** sub-watershed where the winter season consistently experienced the highest loads. The summer season produced the lowest loads in all watersheds during 1991. Overall, the fall season was the most variable from year to year.

The seasonal loads for the winter and spring of 1990 matched quite well with the same periods of 1992 in the Essex paired watershed. During these seasonal periods, marginally higher unit area loads were generated in the **test** watershed compared to the **control** in Essex

as well as Pittock. Also, TSS loads were significantly higher in Kettle Creek **test** compared with the corresponding **control.** Corresponding seasonal flows for the winter and spring of 1990 and 1992 were similar in Essex and Kettle Creek (i.e. same pattern as the loads) but were lower in the winter-spring of 1992 compared to 1990 in the Pittock paired watersheds.

In the Essex paired watersheds, yearly unit area loads were very similar between the **test** and the **control** watershed for all years of record (see Figures 3.7 and 3.10). Yearly TSS loads ranged from 0.31 (t/ha) in Essex **test** in 1991 to 0.88 (t/ha) in 1990 while the **control** produced very similar loads ranging from 0.25 (t/ha) in 1991 to 0.91 (t/ha) in 1990. In the first 6 months of 1992, loading patterns for the Essex paired watersheds did not deviate from the previous years. TSS loads for the January to June of 1992 were 0.38 (t/ha) in the **test** and 0.35 (t.ha) in the **control**. Given the variability in water quality concentrations, the differences found between the **test** and **control** loads are not highly significant.

The Kettle Creek pair of watersheds produced the most variable annual unit area TSS loads, particulary the **test** sub-watershed. Total yearly unit area TSS loads ranged from a low of 0.10 (t/ha) in the **test** in 1989 to 2.23 (t/ha) in 1990. In contrast, yearly unit area loads in the **control** sub-watershed ranged from 0.03 (t/ha) in 1989 to a high of 0.51 (t/ha) in 1990; the latter being less than half the highest load observed in the **test** sub-watershed. During the average and wet years (1989, 1990, and the first 6 months of 1992) the **test** sub-watershed consistently produced significantly higher loads than the **control.** During 1991 the driest year of the study the **test** sub-watershed produced a lower yearly unit area load (0.35 t/ha) compared to the **control** (0.42 t/ha).

Total yearly unit area TSS loads in the Pittock watershed pair were very similar in 1989 and 1992. In 1990, TSS loads were higher in the **test** (0.15 t/ha) than in the **control** (0.09 t/ha). In 1991, **test** produced a lower yearly TSS unit area load (0.29 t/ha) than the **control** (0.43 t/ha). Yearly TSS unit area load ranges were 0.06 t/ha in 1989 to 0.29 t/ha in 1991 in the **test** and 0.05 t/ha in 1989 to 0.43 t/ha in 1991 in the **control** sub-watershed. The first 6 months of 1992 produced TSS loads which were very similar to those of 1989.

Total Phosphorus

Seasonal and yearly total and unit area phosphorus loads are listed in Table 3.6. In both Essex and Kettle Creek watershed pairs, the TP loads exhibited the same general patterns as the TSS loads. This is due largely to the fact that a large proportion of total phosphorus in the discharge is sediment bound. Some minor differences were noted but generally the seasonal trends in TP loads were also very similar to the TSS loads in these two paired watersheds. Annual TP loads ranged from a low of 1.06 kg/ha in Essex **test** in 1991 to 2.90 kg/ha in 1990. Similarly, the lowest annual TP load was encountered in 1991 (0.83 kg/ha) in the **control** sub-watershed while the highest was in 1990 (3.30 kg/ha).

Kettle Creek **test** produced the lowest yearly TP loads in 1991 at 0.87 kg/ha and the greatest TP load in 1990 (5.93 kg/ha). Kettle Creek **control** had the lowest yearly TP load (0.25 kg/ha) in 1989 and the highest in 1990 (3.03 kg/ha).

In contrast to the TSS load patterns, Pittock **test** yearly TP loads were consistently lower than those of Pittock **control**. Yearly TP loads ranged from 0.42 kg/ha in 1989 to 0.99 kg/ha in 1990 in the **test** sub-watershed. In the **control**, yearly TP loads ranged from 0.43 kg/ha in 1989 to 1.32 kg/ha in 1991. It is interesting to note that this trend had reversed in the first 6 months of 1992 where the TP loads were greater in the **test** (0.24 kg/ha) than in the **control** (0.15 kg/ha).

Filtered Reactive Phosphorus

Filtered reactive phosphorus loads (Table 3.7) showed a fairly consistent pattern within each watershed pair. Generally, the **test** sub-watersheds in Pittock and Kettle Creek produced lower FRP loads than the counterpart **control** sub-watersheds especially during periods of heavy loadings. The Essex watershed pair was generally quite similar in FRP loadings, with very similar annual unit area FRP loads in 1989, 1990 and 1992. Only in 1991, a very dry year,

was there a difference; the **control** (0.025 kg/ha) being lower than the **test** (0.093 kg/ha). Generally, FRP loads were the most comparable water quality parameter in terms of magnitude across all watersheds. Pittock generally produced the highest FRP loads, while Essex and Kettle Creek had lower but very similar FRP loads.

A direct comparison of unit area runoff between **test** and **control** sub-watersheds as a means to evaluate the program is somewhat inconclusive at this time. Farm conservation systems were being phased into use over the initial 2 1/2 years of this study and drawing conclusions to their benefit is premature at this time. In concert with the fact that 1989 and 1991 were very dry years, the benefits of implementation cannot be clearly identified from the loading information. Extreme caution should be exercised in using the 1989 and 1991 data sets for comparisons in isolation from following years. The 1990 data set reflects a wet year with more conservation farming in place. Some trends may have emerged through 1990 but the weather patterns of this year have not been replicated since.

In Essex the unit area TSS and TP loadings have been very similar throughout the study (see Figures 3.7 and 3.10). A slight improvement in terms of TP loadings from the **test** sub-watershed over the **control** sub-watershed may have occurred in late 1990. This improvement has been estimated at about a 5% lower **test** unit area TP load by the end of the study period. This relative difference is not statistically significant.

The Kettle Creek **control** sub-watershed outperformed the **test** sub-watershed in terms of water quality loadings for TSS and TP, although TP differences are not significant. The **test** sub-watershed produced higher loads consistently through each year with the exception of 1991. A plausible explanation for this lies in the hydraulics of the two sub-watersheds. The **control** sub-watershed has a relatively flat braided bed and wetland area (south central area) where flow velocities are low compared to the channelized flow. Accordingly, the flow sections in this area does not have the necessary kinetic energy to carry larger particles. This area acts as a sediment trap greatly reducing the rate of delivery of eroded material and

allowing for some phosphorus uptake by wetland vegetation. The **test** sub-watershed has no such deposition zone. During an event in November 1990, samples were taken at six sites within the **control** sub-watershed from the headwaters to the outlet to evaluate the effects of a drain reconstruction in that sub-watershed. Samples were taken from the peak flow for the event. Samples taken in the headwaters had TSS and TP concentrations of 140 to 180 mg/L and 0.40 to 0.75 mg/L respectively. Samples taken immediately downstream of a freshly scraped channel had TSS and TP concentrations of 1381 and 2.45 mg/L respectively, indicating a dramatic impact of the drain works. About one third of the total sub-watershed flow rate was observed at this impacted site upstream of the wetland. However, at the sub-watershed mouth, downstream of the wetland, the TSS and TP concentrations had dropped to 204 and 0.49 mg/L respectively, a reduction by a factor of 5 to 7. Clearly a very large load reduction had occurred in the lower sub-watershed as a result of settling in the wetland. This reduction cannot be accounted for by dilution alone.

Pittock **test** sub-watershed produced about the same unit area loads as the **control** sub-watershed early in the study (1989) in terms of TSS and TP (see Figures 3.9 and 3.12). However, during late 1990 and early 1991, the **control** sub-watershed produced more TP runoff than in early 1990. While overall loadings are low in Pittock, this trend is positive and could be the beginning of a sustained benefit from conservation systems.

In summary, simple comparison of unit area loads of TSS and TP for the entire period of study (January 1989 to June 1992) between **test** and **control** sub-watersheds is not conclusive. Annual average differences tend to be non-significant and seasonal trends are not consistent from one year to the next. In Kettle Creek, a major confounding factor (a depositional area) confuses the comparison necessitating further investigation. Also, conservation systems in all areas were not fully established in all **test** sub-watersheds in terms of the soil structure (and resultant quality benefit factors) which is linked with reduced tillage systems. The overall benefits of the various conservation practices may take years to become fully realized.

3.1.5 Effect of Cover on Watershed Loads

Vegetative cover (live and dead) is a useful general parameter which relates directly to the degree of conservation tillage implemented as well as several other soil parameters such as surface soil moisture and roughness. Cover may also be inversely related to surface detention storage and infiltration.

Table 3.8 identifies the generalized cover patterns (live and dead) for the fifteen most common crop and land use types. This table has been developed based upon cover measurements made three times annually at several sites in the watersheds and documented in Report #4. From this information and cropping information provided by cooperators a table of seasonal cover has been developed for each sub-watershed (see Table 3.9) by season. These represent the best available estimate of total average sub-watershed cover by season.

To examine the effects of cover on watershed loads, the methodology for computing loads was modified to account for periods where cover was dissimilar between the **test** and **control** watersheds. As shown in Table 3.9 percent cover (crop residue and live standing plant) did not change significantly within season over the study period in the **control** watersheds. In contrast, the **test** watersheds of Essex and Kettle Creek show a consistent increase in percent cover in the winter period (January to March) over the study period. In other seasons, particularly the summer months, percent cover is very similar in the **test** and **control** watersheds due to the standing crop.

Once the seasonal loads were finalized, the loading data from the winter period was compiled with the percent cover data to examine the relationship between load, flow and cover. The Fall-Winter time period (November to April) was used in the analysis because this represented the time when cover was most dissimilar between the watershed pairs. Regression analysis was used to derive a relationship between loads (TSS, TP, and FRP), flow, and percent cover. Results are presented in Table 3.10.

Although, there are a limited number of years (four) for which to conduct this type of analysis, most coefficients of correlation (R^2) were reasonably high ranging from 0.58 to 0.99 for TSS, 0.28 to 0.99 for TP and 0.86 to 0.99 for FRP. In all cases flow was positively correlated with load as expected. With regards to percent cover, in several cases loads were negatively correlated to cover as expected (TSS and TP). This type of analysis can be very definitive if the relationship between cover and flow have been determined with some degree of confidence. In the case of the PWS, it is yet inconclusive as to the effect of cover or conservation farm management system on flow. For example, if increased cover resulting from conservation practices increases flow, then a corresponding decrease in water quality concentrations are needed to decrease watershed loads. It is expected that with the addition of new data, this type of analysis can be expanded to include monthly analysis providing that percent cover measurements are collected at an increased frequency. With a longer time frame, it is expected that the type of analysis presented above will become more meaningful.

Another illustration of the effects of cover on watershed loads is presented in the series of Figures 3.13 to 3.18. These figures present selected event unit area TSS and TP loadings for all three watersheds. In two of the cases (Essex and Pittock) the % cover in both **test** and **control** watersheds is very similar. In the case of Kettle Creek events, % cover is much higher in the **test** (48%) compared to the **control** (24%). The event loadings in Essex show three distinct events. Two of the events show that the **control** loading (TSS and TP) rates exceed those of the **test** while in the last peak the reverse is true (Figures 3.13 and 3.14). Figures 3.17 (TSS) and 3.18 (TP) show several Pittock events throughout March 1991. During this period, Pittock cover was very similar in both **test** (32%) and **control** (30%) and as a result event loads are very similar between the **test** and **control** watersheds (except for one large event at the end of March).

The events presented for Essex and Pittock contrast those of Kettle Creek (Figures 3.15 and 3.16). As stated earlier, cover was 48% in Kettle Creek **test** sub-watershed and 24% in the Kettle Creek **control** during March 1991. Four distinct events occurred during this March

period. In all events, both TSS and TP loads were lower in the **test** sub-watershed compared to the **control**. These results can only be attributed to the differences in % cover during this period, particularly when on an annual basis Kettle Creek **test** sub-watershed usually produces higher loads than the **control**.

3.2 Microbasin Scale

3.2.1 Background

As discussed in the hydrologic evaluation report (see Report #5), the microbasin monitoring program was designed to allow for field level runoff and water quality loading analysis. These microbasins represent the intermediate scale of monitoring in this study. Microbasin areas range from 4.1 to 28.0 ha (about 1 to 8% of sub-watershed areas). The data from the microbasin level monitoring provides for comparison of areas consisting of one to five fields therefore involving much less complexity than the entire watershed scale in terms of land use, soil types and drainage.

Given the size and slope of the these microbasins, the frequency, duration and variable distribution of precipitation; and the rapid flow response time, not all microbasins produced runoff and associated water quality loadings as regularly as do the main watershed outlets. The microbasin scale does not measure groundwater runoff and is almost totally due to surface overland flow. A number of other factors such as monitoring equipment failure, high flow backwater effects and occasionally, flooding of monitoring equipment, has further reduced the accuracy of some flow events at this scale. Due to these factors and the variability of precipitation, total flows are not necessarily comparable from microbasin to microbasin within a watershed for the entire yearly duration.

3.2.2 Water Quality Chemistry

To be effective in reducing pollutant loadings to receiving waters, a farm conservation practice must reduce soil loss or runoff or both. It has been shown in Report #5 that no-till systems resulted in an increase of runoff volume in some cases, (especially in Essex microbasins). However, increased runoff may be associated with decreased TSS concentrations and an overall reduction in loadings. In this section, the microbasin water quality chemistry will be examined to determine if any trends exist.

Microbasin water quality summary statistics are presented in Appendix C. The data includes average, median, maximum, minimum, standard deviation, coefficient of variation, and upper quartile and lower quartile concentration information. The discussion regarding water quality data will be limited to average and median concentrations for each year of the study. The statistical summaries were produced using the calendar year as the basis because the limited amount of data in any given year would not allow for further partitioning into, for example, seasonal analysis.

Table 3.11 contains the average and median total suspended solids concentrations for each year. In the Essex **test** microbasins average and median TSS concentrations have decreased consistently since 1989. In contrast, the **control** microbasins have been inconsistent with both average and median TSS concentrations showing no trends. In the Kettle Creek **test** microbasins, no event flows were recorded in 1989 and therefore the comparison has been limited to 2.5 years. However, KTB2 has shown a decrease in average and median TSS concentrations since 1990, while the other microbasins have been inconsistent. Microbasin KCB1 has shown a consistent increase in average TSS concentrations since 1989. Confounding the effects of examining water quality chemistry in KCB2, was the installation of tile drainage in most of the basin in the fall of 1990. While the total event flows did not decrease significantly as a result of the tile drainage, the amount of surface runoff and potential soil loss did decrease.

In the Pittock watershed, none of the microbasins produced useful water quality data in 1989 and very little in the remaining years in both of the **control** microbasins. Flow events were extremely rare in PCB1 and PCB2. Pittock overall did not yield much surface water runoff throughout the entire study period and when surface runoff did occur, the flow events were rather minor in comparison to Kettle Creek and Essex areas. Given the silt loam soils, the excellent soil hydraulic characteristics in the Pittock area, and the lower than normal precipitation in the area, the Pittock sub-watersheds did not produced significant soil loss events.

Table 3.12 contains a summary of average and median total phosphorus concentrations. The trends in TP are very similar to the TSS trends. This is not surprising given the fact that most of the phosphorus loads are associated with the particulate soil bound form.

In general, the microbasins in Kettle Creek and in Essex have provided useful data for the field scale comparison of conservation practices for the short term. The data collected will also provide the basis of comparison for future evaluations. Further data collection will be necessary in order to examine trends at this level of monitoring given the fact that flow events are discontinuous and often infrequent and significant flow events have been rare.

3.2.3 Microbasin Loads

As discussed previously, the microbasins are variable in response and often do not all produce runoff during a given rainfall event. For this reason, the data presented herein contains event loadings which are comparable or produced runoff loadings for most microbasins within a watershed. Table 3.13 contains the number of microbasin events in each of the watersheds over the study period. It can be seen from the information in Table 3.13, that the Kettle Creek microbasins (particularly the **control** microbasins) produced the greatest number of flow events. In the case of the Kettle microbasins, KCB2 produced 54 flow events while KCB1 produced 51. The **test** sub-watershed microbasins, KTB1 and KTB2, produced 22 and 25 flow events respectively over the monitoring period. Pittock microbasins produced 14 (PCB1,

PCB2) to 29 (PTB2) events over the study period. However, most of the events in Pittock were very minor in nature producing very little total flow. Essex events were the fewest in number ranging from 8 (ECB1) to 20 (ECB2). In contrast to Pittock, the Essex events were often high flow events.

As shown in Tables 3.14 to 3.16, the most frequent event loadings periods were in the spring and fall when soil moisture conditions were conducive to producing runoff. Very little runoff occurred in the microbasins during the summer months when evapotranspiration exceeded total precipitation, and soil moisture levels were generally low. In addition, two of the three summers in the study period produced drought-like conditions. Other factors affecting the microbasin events include the fact that the watersheds (particulary Kettle Creek and Pittock) were near the sources of their major watershed drainage basins and, therefore, the effects of groundwater and soil water on the microbasin flow were limited. In other words, there was very little contribution of groundwater to the overall microbasin flow. Groundwater levels often dropped to 3-5 metres below the soil surface in the dry summer drought months (see Section 3.4). Therefore, much more precipitation was needed just to replenish soil and groundwater levels before runoff would occur on a regular basis in the microbasins or even at the whole watershed level. As a result of these occurrences, the total number of comparable microbasin events is limited. Nonetheless, there is useful and meaningful data regarding field scale runoff and loadings for each of the microbasins.

Unit area water quality loadings for microbasins are presented Appendix C and select microbasin events used for comparison are presented in Tables 3.14 (Essex), 3.15 (Kettle Creek), and 3.16 (Pittock). In most cases, it can be seen that the periods when most microbasins produced comparable event loads were the Spring and Fall. As can be seen from that data presented in Tables 3.14 to 3.16, water quality loadings show no immediate or distinctive trends with respect to time or basin type (**test** or **control**). Comparisons can be made on an event-by-event basis examining loads with respect to flow. Using standard trend analysis, the data presented in Tables 3.14 to 3.16 and the data in Appendix C, a relationship between load and flow was determined for each microbasin.

Figures 3.19 through 3.22 contain plots of unit area flow and load (logarithmic scale) for the **test** and **control** microbasins. The Pittock **control** microbasins had too few events to generate reliable plots of load and flow. TSS and TP loads were used in this comparison. The **test** and **control** cover estimates were made from actual field measurements and interpolation for periods which were not measured. Cover for the entire microbasin was an area of weighted average of the cover for fields within the microbasin. For the purpose of statistical analysis, the two **test** microbasins were combined as were the **control** microbasins. Furthermore, the LS factor (Wischmeier and Smith, 1978) was estimated for each microbasin and all unit area event flows were divided by LS in order to normalize microbasins to account for differences in slope and slope length.

As indicated in each graph a consistent trend has emerged during low flows, loads are higher in the **test** microbasins in each of the watershed pairs. This indicates an inherent tendency for the **test** microbasins to generate higher loadings in both areas. However, during moderate to high flow events the **control** microbasins produce greater loads. In this form of evaluation a flatter slope indicates a condition which has a tendancy to lower runoff. This is the case with the **test** microbasins. In each of the figures an inflection point occurs. This inflection is the point at which, at given flow, loads are equal in the **test** and **control** microbasins. At flows higher than the inflection point, water quality loads are higher in the **control**. Therefore, the flow at which the inflection point occurs determines the flow/benefit effectiveness of the conservation practices for a given watershed. In Essex the inflection point flow is less than 10 cubic metres per hectare for both TSS and TP. In the Kettle Creek watershed, the inflection point flow is 80 cubic metres per hectare. There was unfortunately insufficient data to conduct this type of analysis for the Pittock watershed. This trend can be explained by differences in cover since the **test** microbasins had, on average, 15 and 23% higher cover than the **control** microbasins in Essex and Kettle Creek respectively.

3.3 Rainfall Simulation

Every effort was made to select rainfall simulation sites which were as similar as possible in terms of soils, topography and management practice yet still permit access for rainfall simulation equipment. Since it was not always possible to select sites which exhibited similar traits for all characteristics, crop type was deemed to be the most important factor. Differences which did exist between the **test** and **control** sites were quantified to aid in the interpretation of the data.

Site Characteristics

Soils at both of the Essex sites are clay loams. The Kettle Creek **test** site is also a clay loam soil while the **control** site is a silt loam. The Pittock **test** sites are situated on silt loam soils while the **control** sites are on loam soils. Although there appear to be some differences between **test** and **control** textures, the sand, silt and clay contents are quite close for each pair and have only been classed differently because one lies just on the other side of the texture boundary in the soil texture triangle (see Beak Consultants Limited, 1991).

Characteristics of the rainfall simulation sites including management practice, residue cover, slope and antecedent moisture content are summarized in Table 3.17. Results in this table are the mean values for the three replicates. Individual data are found in Appendix D.

Ideally, the crop residue cover percentages would be significantly different between sub-watershed pairs for all seasons except for Post-Harvest91. Since Post-Harvest91 occurs after harvest prior to fall tillage, the conservation practice should show similar residue to the conventional site except for some differences in plant population and yield. As pointed out in Table 3.17, no significant differences in crop residue cover are noted for Kettle Creek and Pittock for the Post-Harvest91 runs but a significant difference is noted in the Essex watershed. However, the Essex sub-watershed pairs are very similar with 54 and 67 percent

cover for the **test** and **control** sub-watersheds respectively. Due to the low variance within the replications, these numbers were not statistically different (95% level of confidence). Also noted in Table 3.17 is that the Pittock sub-watershed pairs measured in the fall of 1990 (Post-Tillage90) show no significant difference in residue cover. This indicates that the modified moldboard plow does not result in an increase in residue left on the surface after tillage.

Similar slopes between the **test** and **control** sites were desirable but not always feasible as is evident in Table 3.17. However, the effect of slope on erosion over only a 1 m distance is not expected to be large. The fact that many of the pairs exhibited different slopes is not particularly important given that the greatest difference is only 6 percent.

Antecedent moisture content would also be similar for all sub-watershed pairs under ideal field conditions. However, due to the effect of surface residue on soil moisture, similar moisture contents were not anticipated. Moisture content of the soils ranged from a low of 8.8 % in the Kettle Creek **control** site prior to the post harvest simulation of 1991 (Post-Harvest91) to a high of 37.3 % at the Pittock **test** site in the fall of 1990 (Post-Tillage90).

In general, statistical analysis showed a significantly greater mean antecedent moisture content in the **test** soils (25.6%) compared to the **control** sites (22.1%). This is likely due to the increased moisture holding afforded by crop residue which is generally higher in **test** plots. When all **test** and **control** sites were grouped together, Essex had the highest mean moisture content (29.1%) followed by Kettle Creek (23.5%) and Pittock (18.9%). In terms of seasonal differences in moisture content, Post-Tillage90 was significantly wetter than all the other seasons and PP92 was significantly drier than the others. No significant differences were noted between PP91, Post-Harvest91 and Post-Tillage91.

Total Suspended Solids

Analytical results from the BAS laboratory provided information on the concentrations of total suspended solids in the runoff samples. The range of TSS concentrations for all runs was very

great. The lowest TSS concentration measured was 671 mg/L obtained from the third replicate on the Pittock **control** site in the fall of 1991 (Post-Tillage91). The highest TSS concentration of 96600 mg/L was observed on a Kettle Creek **control** plot (second replicate) also in the fall of 1991 (Post-Tillage91).

Although mean concentrations were often greater in the **control** samples than in the **test** samples, statistical analysis showed that significant differences (95% level of confidence) occurred only in the Post-Tillage90, PP91 and Post-Tillage91 runs in Kettle Creek and the Post-Tillage91 runs in Essex. These findings seem to indicate that the runoff from the Kettle Creek **test** sites which were under continuous no-till corn was significantly cleaner than that from the moldboard plow sites.

More important than the concentration of runoff is the total load or mass of soil moved off of the plot. Because of this fact, this discussion will deal primarily with loads. The loads have been calculated by multiplying the concentration of TSS by the total runoff volume. Individual concentration data are found in Appendix D. Note that **true** concentrations are obtained from the laboratory concentrations but are corrected for the wash water volume used to rinse the collection trough.

When examined for all watersheds for all seasons, mean TSS loads from the **test** sites were significantly (95% confidence level) lower (14.28 gm/m^2) than the **control** site loads (28.67 gm/m^2). From a watershed standpoint, TSS loads did not differ significantly between watersheds. On a seasonal basis, the greatest loads were obtained in the PP92 runs (44.19 gm/m^2) followed by PP91 (34.34 gm/m^2) and Post-Tillage90 (18.13 gm/m^2). Runs from Post-Harvest91 and Post-Tillage91 yielded the lowest TSS loads at 5.62 and 5.07 gm/m^2 respectively.

The following sections discuss **test** and **control** site comparisons for each of the three watersheds. Figure 3.23 summarizes the total TSS loading data set and provides levels of confidence and % cover.

Essex

Figure 3.23 illustrates that for most seasons, TSS loads generated were greater on the **control** sites relative to the **test** sites except for the post harvest runs (Post-Harvest91). The PP runs combined were significantly different at a 94% level of confidence with **control** plot loads averaging about three times more erosion than **test** plots. During the Post-Tillage runs combined the **control** plot TSS loads exceeded **test** plot loads by a factor of about two at a 92% level of confidence. In the PP91 run, exceptionally high TSS loads were generated from the **control** plots due primarily to high runoff volumes from all replicates and one extremely high TSS concentration in replicate 3 (See Appendix D for individual replicate data). The average TSS concentrations in Pre-Plant period runoff for **test** and **control** plots was 4,330 mg/L and 9,114 mg/L respectively. As discussed in Report #5 concerning the hydrologic aspects, the Essex **control** runoff volumes for the pre-plant runs were almost double that of the **test** plots on average. Runoff volumes were not significantly different between **test** and **control** plots during the Post-Harvest and Post-Tillage tests in Essex.

Kettle Creek

Figure 3.23 shows TSS loads generated from the Kettle Creek plots. As in Essex, the mean TSS loads were greater in the **control** sites compared to the **test** sites except for the PP91 season. Statistical analysis indicates, however, that at no time were the differences statistically significant (at a 95% level of confidence). The hydrological analysis (Report #5) indicated that the **test** plots generated significantly more runoff than the **control** plots during the Pre-Plant and Post-Tillage runs. On average the **test** plot runoff exceeded **control** plot runoff for those periods by a factor of 3 to 4 times. Therefore, clearly the **test** runoff was much cleaner during these periods such that total runoff loads were similar to the **control** plots. In fact, the average TSS concentration in the **test** and **control** plot runoff for the Pre-Plant and Post-Tillage periods was 1,740 mg/L and 24,489 mg/L respectively. Clearly the **test** plots in Kettle Creek produced higher runoff volumes with much cleaner runoff water for the Pre-Plant and

Post-Tillage periods. The Post-Harvest period produced low runoff volumes and loads in all cases. In effect the conservation systems have produced more runoff but this has been more than compensated for by the reduction in erosion.

Pittock

Figure 3.23 provides the mean TSS loads for the Pittock watershed. In all cases except Pre-Plant92, TSS loads were actually greater in the **test** areas. The differences in mean loads were only significantly different in the spring of 1992 runs (Pre-Plant92) where the mean **control** load was larger.

The **test** plot runoff was significantly higher (at a confidence level of 85%) during the Post Harvest period. This accounts for most of the difference observed in Post Harvest loads. Total runoff was similar between **test** and **control** plots for the Pre-Plant periods. Therefore, higher average TSS loads at this time are largely due to higher **control** plot TSS concentrations. The **test** and **control** Pre-Plant TSS concentrations were 4,457 mg/L and 10,605 mg/L respectively.

The **test** plots produced higher TSS loads during the Post Tillage periods. This was due to much higher runoff from **test** plots at that time as one would expect since the **test** plots were undisturbed while **control** plots were highly disturbed with high depressional storage.

Individual site comparisons of TSS loads between **test** and **control** plots showed differences at confidence levels above 80% in five of nine comparisons. The Post Harvest period displayed less obvious differences as one would expect since at this time land surfaces are similar with high plant residue levels. During this period the **test** plots in Essex and Pittock produced more runoff and similarly more TSS loadings. The reverse was true in Kettle Creek. All loads were low, however, after harvest.

During the Pre-Plant periods all TSS loads were much higher and in all cases the **control** plots produced higher TSS loadings. This was due to higher runoff volumes in Essex and higher TSS concentrations in all areas. Loadings were the highest during this period in all cases.

During the Post-Tillage periods the TSS loadings in Essex and Pittock followed the runoff volume trend. The reverse was true in Kettle Creek as the **control** plot runoff contained much higher TSS concentrations. These results are summarized in Table 3.18.

When all runs are lumped the TSS loads for **test** plots are lower than for the **control** plots. The greatest benefit of conservation systems is shown to occur during the pre-plant periods when overall loads were the highest.

Total Phosphorus

Like the TSS concentrations, ranges in concentration of total phosphorus in runoff varied greatly. The lowest value of TP (0.01 mg/L) was found in replicate 3 of the Kettle Creek **test** plots in the spring of 1991 (Pre-Plant91). The highest concentration (250 mg/L) was obtained from a sample taken in the fall of 1990 (Post-Tillage90) on replicate 1 of the Kettle Creek **control** site. Only at Kettle Creek during the Post-Tillage90 runs were TP concentrations significantly lower in the **test** samples.

When all **test** sites were grouped together and similarly, all **control** sites were amalgamated, TP loads from the **test** sites were significantly (at a 95% level of confidence) lower (0.022 gm/m^2) than the **control** loads (0.041 gm/m^2). This follows the same trend as seen with the TSS loads. The similar trend is not unexpected since most phosphorus travels in the particulate phase held tightly to soil particles. Following the trend of the TSS loads again, no significant difference in TP loads was noted between the three watersheds. Seasonally, TP loads were lowest in the fall of 1991 (0.0094 gm/m^2 for Post-Harvest91 and 0.0069 gm/m^2 for Post-Tillage91). The greatest TP loads were obtained during the Pre-Plant92 runs (0.0611

gm/m^2) and Pre-Plant91 (0.0496 gm/m^2). Post-Tillage90 was in the middle with average TP loads of 0.0324 gm/m^2. Pre-Plant91 and Pre-Plant92 loads were not significantly different from Post-Harvest91 and Post-Tillage91. Post-Tillage90's means TP load was not significantly different from any of the other seasons.

Figure 3.24 summarizes the data set and provides levels of significance and cover levels.

Essex

In Essex, total phosphorus loadings followed the same patterns as TSS. **Control** plot TP loadings exceeded **test** plot loadings during the Pre-Plant and Post-Tillage periods. These trends were due to higher **control** runoff volumes and higher TP concentrations. During these two periods combined the average **test** and **control** TP concentrations were 4.25 mg/L and 11.8 mg/L respectively.

During the Post-Harvest period the **test** plot TP loadings were higher than in the **control** plots due to higher runoff volume and concentrations.

Kettle Creek

The Kettle Creek plot TP runoff loadings were somewhat different than the TSS loading trends in the Post-Harvest and Post Tillage periods. The Pre-Plant period TP loadings followed the same pattern as TSS with higher **control** plot loadings due to much higher TP concentrations (1.4 mg/L in **test** plots and 19.4 mg/L from **control** plots) despite lower runoff volumes.

The Post-Harvest and Post-Tillage periods both displayed higher **control** plot TP loadings although in both cases differences were small. In these two periods **control** plot TP concentrations were higher at 43.8 mg/L compared to 4.0 mg/L for the **test** plots. Runoff was

much higher in the **test** plots during post tillage, but the reverse was true during the post harvest period.

Pittock

Pittock plot TP loadings followed the same trends as the TSS loadings. In this area, the **test** plot TP loadings exceeded the **control** plot loadings in the Post-Harvest and Post-Tillage periods due to higher **test** plot runoff volumes. Total TP loads were low in both periods. More significantly, the **control** plot TP loadings exceeded the **test** plot loadings during the Pre-Plant period when loads were high. During this time period the **control** plot TP concentrations were higher at 12.4 mg/L compared to 8.1 mg/L for the **test** plots.

Table 3.19 summarizes the observations regarding TP loadings.

In summary, the mean TP loads followed similar trends to the TSS loads in that few differences were noted when observed on individual watersheds at separate times. Still, when combined and examined together, reduced TP loads were observed on the test sites. As mentioned earlier, the most likely reason for the lack of significant differences noted on an individual basis is the low number of replicated plots for analysis.

Correlations Among Parameters

Correlations and regression analyses were employed on the water quality data set to determine if any significant relationships existed among the parameters. No significant relationships were noted between the parameters.

Multiple regression analysis was run to establish the equation to determine TSS load and TP load using runoff, residue, moisture and slope. The resulting equations and their r^2 values are reported below.

TSS Load = 0.0033 x runoff - 0.3380 x residue + 0.8959 x moisture - 1.312 x slope

$r^2 = 0.5037$

TP Load = 5.208E-06 x runoff - 5.529E-04 x residue + 0.0015 x moisture - 0.0022 x slope

$r^2 = 0.518$

Neither of the resulting equations is highly valid because of the relatively low r^2 values. Runoff and soil moisture are positively correlated to loads and residue is negatively correlated as expected. It is interesting to note, however, that in both equations, slope is negatively correlated to load. This is in direct conflict with the Universal Soil Loss Equation which identifies a positive correlation between percent slope and erosion.

The Effects of Cover

Figures 3.23 and 3.24 are TS and TP loads for the rainfall simulation runs. Also included in these figures are the percent cover (live and dead) for all three watersheds. During the Post-Harvest periods cover values are similar because crop residue dominates the overall cover and therefore both plots have high cover levels. Therefore during these periods cover is not an effective independent variable. The studies documented here generally indicate that **test** and **control** plots do not behave significantly different in terms of runoff volumes or in terms of TSS and TP loadings during the Post-Harvest period. The high cover levels (54% to 91%) and lower soil moisture at this time also result in low levels of runoff and chemical loadings.

During the Pre-Plant and Post-Tillage periods, cover does differ significantly between **test** and **control** plots at 68% and 12% respectively. Accordingly, during these periods significant differences exist in terms of runoff volumes and loadings. In all watersheds **control** plot loadings of TSS and TP exceed **test** plot loadings during the Pre-Plant period. These exceedences are significant at levels ranging from 63 to 96%. In the case of Kettle Creek and Pittock the **test** runoff volumes were higher but this fact is more than affected by high **control** plot concentrations.

The Post-Tillage periods is more difficult to characterize since two factors are at odds in this case. **Test** plots have higher cover values but the **control** plots are freshly tilled and therefore runoff values tend to be lower as the soil surface is capable of retaining more water in depressional storage. However, **control** plot runoff water contains higher concentrations of TSS and TP in all cases. This is almost certainly due to the fact that cover values are lower and therefore soils are more exposed to raindrop impact.

3.4 Groundwater Chemistry

Throughout the SWEEP Pilot Watershed Study period, groundwater samples were collected, using a foot-valve pump sampler, from paired piezometers located in both the **test** and **control** sub-watersheds at Essex, Kettle Creek and Pittock. All collected samples (unfiltered) were analyzed for total phosphorous (TP) content. The complete set of groundwater TP data is presented in Appendix E.

A summary of the TP data is presented in Table 3.20. Each piezometer was subject to conditions of freeze-up or drying out during periods that did not necessarily correspond between sub-watersheds. Accordingly, the number of samples obtained from each piezometer within a given watershed is not uniform.

Overall, groundwater from the Pittock sub-watersheds had the highest TP concentrations of the three watersheds (see Table 3.20). Average groundwater TP concentrations were 0.247 mg/l and 0.184 mg/l for the two piezometers in the Pittock **Control** sub-watershed and 0.268 mg/l and 0.136 mg/l for the **Test** sub-watershed. Essex had the second highest overall groundwater TP concentrations with averages of 0.041 mg/l and 0.037 mg/l in the **Control** and 0.083 mg/l and 0.182 mg/l in the **Test** sub-watershed. The Kettle Creek watershed had the lowest overall groundwater TP concentrations with an average of 0.013 mg/l and 0.007 mg/l in the **Control** and 0.21 mg/l and 0.04 mg/l in the **Test** sub-watershed.

Average annual TP concentrations are presented in Table 3.21. There are only two noticeable trends in TP concentration with respect to time. First, most sampling sites, with the exception of those in Kettle Creek **control** and one site in Kettle Creek **test**, exhibit the highest TP concentrations in 1991. This was also the year with the lowest annual total precipitation in the three watersheds. The second temporal trend is that most sampling sites exhibit the lowest TP concentrations in 1992 except for one piezometer in each of Kettle Test, Pittock Control, and Pittock Test (see Table 3.21). However, samples collected in 1992 only represent the first six months of the year and may not accurately reflect the protracted annual average due to possible seasonal variability.

4.0 DISCUSSION AND CONCLUSIONS

4.1 Discussion

4.1.1 Watershed Scale

Parameter Concentrations

Analysis of water quality data trends over time is useful for the assessment of effectiveness of land conservation practices in improving receiving water quality. Analysis of manually obtained duplicate water samples from the watershed outlets show a good overall degree of reliability in the water quality data set which facilitates direct **test** and **control** comparisons.

The TSS concentrations at the six watershed outlets are quite variable both in time and with respect to location (i.e. **test** or **control** sub-watershed). The variability is due to a variety of sources including climatic parameters such as precipitation and temporal dependent variable parameters such as % cover, soil moisture balance, farm management, etc. However, trends do exist that indicate an ameliorative effect of conservation practices on water quality.

In the Essex watershed, the **test** sub-watershed exhibits higher TSS concentrations than the **control** throughout the study period except for the first six months of 1992. However, concentrations of TSS at the **control** sub-watershed outlet fluctuated over the study period while **test** TSS concentrations consistently decreased to a point where they were lower than those of the **control** (Jan. to June, 1992). This parallels the increased use of land conservation practices in the **test** sub-watershed and is therefore evidence that conservation practices may improve the quality of surface runoff from agricultural lands regardless of whether runoff quantity had increased.

In the Kettle Creek watershed, TSS concentrations were again higher in the **test** than in the **control** except in 1991 when average annual TSS concentration was higher in the **control**. Neither the **test** nor the **control** sub-watershed exhibited a consistent increase or decrease in TSS over the study period. From a hydrologic point of view, these two watersheds are very different which has resulted in consistently lower TSS concentrations in the **control** sub-watershed. A large , flat wetland area in the control is likely a significant factor contributing to the lower TSS concentrations at the **control** outlet. Flow through this area is slow and far less turbulent to a point where sediment settles, thus reducing the total sediment delivery to the sub-watershed outlet. This is a major confounding factor in assessing the effectiveness of the **test** versus **control** design.

Given the fact that the Kettle Creek sub-watersheds are very different hydrologically, only two means of evaluating the effectiveness of the **test** versus **control** design can be made. The first is to examine long-term trends in water quality chemistry and loads in both watersheds. Ideally, through long-term trend analysis, the **test** (with large scale adoption of conservation practices) watershed should have improved water quality over time. In contrast, the **control** is not expected to show this improved water quality trend. Secondly, an examination and characterization of water quality upstream and downstream of the **control** wetland would quantify the effect of this sediment detention area. This would ultimately have to be conducted during a variety of flow events to have any confidence in the assessment. Ultimately, a combined long-term monitoring approach and more detailed water quality characterization of the Kettle Creek **control** sub-watershed would be ideal.

TSS concentration at the Pittock watershed was lower at the **test** outlet than at the **control** except for during the first six months of 1992, when both the **test** and **control** TSS concentrations were very low. No consistent temporal trends exist for either sub-watershed over the study period. Overall, the lower **test** TSS concentrations are positive evidence of the potential water quality enhancement of conservation practices.

TP concentration at the watershed outlets follows similar patterns to TSS, since a large proportion of the total phosphorous content is sediment bound.

In Essex, TP concentration was consistently higher at the **test** sub-watershed outlet, but decreased in every year except 1991.

In Kettle Creek, TP concentration at the **control** sub-watershed outlet increased in each successive year except for the first half of 1992 while the **test** showed no consistent increase or decrease.

Seasonal TP concentration at Pittock was consistently highest at the **control** outlet for the period of January to March.

With respect to FRP, minor trends similar to those for TSS and TP were exhibited at the watershed outlets.

FRP concentration was consistently higher for Essex **test** than for Essex **control**. After an initial increase from 1989 to 1990, **test** FRP concentration dropped in each successive year. The same temporal trend is exhibited by the Pittock **test** sub-watershed. Kettle Creek **test** had consistently lower FRP concentrations than the **control** sub-watershed except during the first six months of 1992.

Parameter Loads

The load modelling procedure used to generate the reported loads functions by producing an equation relating loads to observed flows. The equation contains coefficients A and B fitted using a power curve. A correlation coefficient (R^2) provides for a measure of data fit to the power equation. The ranges of correlation coefficients were generally very good for the three parameters of concern. Values of the coefficient B produced for TSS and TP in the watersheds were within the range of corresponding values reported in the literature.

As with concentrations of water quality parameters, loads are quite variable in time, especially in the fall season, and with respect to location.

No consistent trends in **seasonal** TSS loads were exhibited except in the Kettle Creek **test** sub-watershed where the winter season consistently experienced the highest loads.

In the Essex watershed, **annual** unit TSS area loads where similar for the **test** and **control** sub-watersheds in every year of the study.

In Kettle Creek, the **test** sub-watershed outlet had higher TSS loads than the **control** except during 1991, a very dry year. As with TSS concentration, a partial explanation for low **control** TSS loads is the wetland area situated in the **control** sub-watershed.

In the Pittock watershed, TSS loads were not consistently higher in either of the sub-watersheds and therefore inconclusive.

Loadings of TP were similar in pattern to TSS loads, since a large portion of the TP is delivered in a sediment bound form.

As with TSS, annual unit area TP loads were similar for the **test and control** in the Essex watershed. Also, TP loads were higher in Kettle Creek **test** than in the **control** in every year except for the first half of 1992, likely for the same reason as for the same pattern of TSS loads in Kettle.

In Pittock, the **test** sub-watershed outlet had lower TP loads than the **control** in every year except for the first half of 1992, when both sub-watersheds had very low TP loads.

FRP loads did not follow the same pattern as TSS and TP, except in the Essex watershed where annual unit area FRP loads were approximately equivalent for the **test and control** sub-watersheds.

Generally, FRP loads were lower at the **test** outlet than at the **control** outlet in both Kettle Creek and Pittock, especially during periods of heavy loadings.

Overall, simple comparisons of loads and concentrations of the water quality parameters are not conclusive. However, these comparisons are indicative of some differences between **test** and **control** sub-watersheds (i.e. lower or decreasing loads and concentrations over the study period in some **test** sub-watersheds) and accordingly are indicative of potential benefits of land conservation systems.

Cover

Effects of cover (live or dead plant material) on surface water quality at the watershed outlets are still inconclusive, yet some generalities may still be extracted from this study.

As with any agricultural erosion study, flow and load are interrelated. Normally, TSS and TP load increases with increase in flow. However, when studying the effects of conservation practices, percent land cover is often examined for its effect on water quality loads. In many cases studies have shown a negative correlation between percent cover and watershed load. However, these studies have focused on the plot or field scale. Fewer studies have examined the effect of cover on watershed scale loads. Results from the PWS indicates that what holds true for the plot and field scale is also true at the whole watershed scale. In some cases, at the watershed scale, flow was negatively correlated with percent cover. This indicates that increased cover may correlate with decreased loads. Over the study period, both Essex and Kettle Creek **test** sub-watersheds showed steady improvement in terms of percent cover and to some degree a decrease in water quality loads.

In addition, there is probably some complexity due to scale (i.e., trends less apparent at large scale over the short-term). In some cases at the watershed scale, improvements in water quality runoff in certain areas with conservation practices are being overshadowed by other

area lands that may still remain with conventional systems. It is this complexity and uncertainty that has to be examined over the long term to quantify variability and overall trends.

4.1.2 Microbasin Scale

Parameter Concentrations

In Essex, TSS concentration consistently decreased in the **test** microbasins while showing no trends in the control **microbasins.** The same decreasing trend was observed for one of the **test** microbasins in Kettle Creek while the other microbasins (**test and control**) were inconsistent. This decrease in TSS in **test** microbasins is evidence of potential positive effects of land conservation practices on water quality. The lack of flow events in the Pittock **control** microbasins makes comparisons less conclusive.

Microbasin TP concentrations follow a very similar pattern to TSS concentrations, for reasons as stated for watershed scale TP concentrations. Again, this is partially indicative of a positive impact of conservation practices on water quality.

The rarity of significant microbasin flow events provides evidence for the need for continued study and expansion of the database in order to draw firm conclusions. What is ultimately required is to examine similar flow events at similar times of the year for an extended period of time. This would not only define inherent natural variability, but improve the data set in order to conduct the **test** versus **control** design. As is hypothesized, the benefits of conservation practices improve over time and it is imperative to examine and quantify the expected associated improvements in soil and water quality.

Parameter Loads

Overall, unit area microbasin loads show no distinct trends with respect to time or location (**test** or **control**). Again, the rarity of significant microbasin flow events makes it difficult to make firm conclusions and underscores the need for further study.

Correlation analysis of lumped microbasin loading data allows for a comparison of **test** and **control** loads for both Essex and Kettle Creek watersheds. In both cases, TSS and TP loads were higher in the **test** at low flows but were higher in the **control** at moderate to higher flows. Flatter slopes for the **test** microbasin plots are indicative of cleaner runoff and more erosion protection than **control** microbasins. This indicates a possible advantage to land conservation practices in the enhancement of water quality during the most significant periods of contaminant loading. Often the largest proportion of total yearly TSS and TP loads are comprised of two or three large flow events. The results of the microbasin analysis suggests that, in the case of these large events the lands that have a history of conservation practices will yield lower erosion rates and thus lower TSS and TP loads to receiving waters. It should be kept in mind that this trend of lower loads in the **test** microbasins during high flow events was assembled during what must be considered a dry period with relatively few major microbasin events. It is anticipated that given an extremely wet year with several high flow events, this trend would become even more pronounced and the ultimate benefits of conservation practices would be more conclusive.

4.1.3 Plot Scale

The rainfall simulation component of the PWS water quality evaluation produced the most obvious and predictable results. This is due to the controlled nature of these tests in terms of area, land management, rainfall intensity and time, and precise measurement of runoff, soil moisture, slope and residue. Triplicate tests have also been possible which has reduced variability.

The hydrological analysis of rainfall simulation studies produced some conflicting results. That is, some plots produced more runoff under higher crop cover conditions and others produced less runoff. Also, plot trends in runoff conflicted with microbasin scale trends in some cases. These tests may be the best indicator of the highly variable and complicated nature of runoff. Despite control over several variables, runoff prediction was found to be unreliable. Undoubtedly, microscale factors relating to plot roughness, macroporosity, microporosity, and slopes are important and difficult to characterize.

When water quality data and loads are determined, the benefit and effect of conservation tillage becomes much cleaner. **Test** plots had significantly lower loads of TSS and TP, often due to lower TSS and TP concentrations in **test** plot runoff. This was particularly true for the Pre-Plant period which generated the highest unit area loads by far and for the Post-Tillage period which generally produced the next highest loads of the three time periods examined. In fact, in Essex, the **control** plots produced significantly more TSS and TP loadings during these two periods, primarily due to higher runoff volumes and concentrations. Essex results reflected the most obvious benefit of conservation systems because both runoff volume and concentration decreased under conservation tillage and higher crop cover levels. The Post-Harvest period produced small loadings of TSS and TP and does not represent a good test of conservation systems because of the similarity in crop cover at these times.

In Kettle Creek, the TSS and TP loads from the **control** plots generally exceeded that from the **test** plots. However, during the Pre-Plant period the **control** plot runoff was lower than from **test** plots and the TSS and TP concentrations from the **control** plots was much greater, so much so that the effect of lower **control** plot runoff was more than compensated.

During the Post-Tillage period, the Kettle Creek **control** plots produced much lower runoff. Higher **control** TSS concentrations resulted in higher **control** plot loads, compensating for the lower runoff volumes. The reverse was true for TP as **test** plot concentrations exceeded **control** plot concentrations. Post-Harvest loads were low, and because of similarities in cover, the results are inconclusive.

In Pittock, the **control** plots also produced more runoff loadings of TSS and TP during the Pre-Plant period due to higher concentrations. During the Post-Tillage period the **test** plots had produced much more runoff and, coupled with similar concentrations, the overall **test** loads were higher. In this time period the tilled **control** plots are much more disturbed and can retain a significantly higher amount of the rainfall in depressional storage. The same trend was apparent during the Post-Harvest period in Pittock as **test** plot runoff volumes were higher resulting in higher **test** loadings. Overall loadings were low during the Post-Harvest tests.

The Post-Tillage and Pre-Plant periods bracket a significant period of the year usually from early fall to early summer and represent an erosion prone period with minimal live plant cover. The studies conducted here show that during this period conservation tillage reduces TSS and TP loadings. This is shown to be true even in areas where conservation tillage increases runoff, because concentrations of TSS and TP tend to be much higher in the runoff from **control** plots. During the brief period following tillage, some **test** plots may generate more runoff, TSS, and TP loads because of the relatively undisturbed surface compared to the tilled plots. However, this effect is likely to be short-lived as tilled surfaces become smooth following wind and rain events.

4.2 Conclusions

4.2.1 Watershed Scale

- The watershed scale proved to be the most complex in terms of inherent variability, of climatic, soil, runoff and erosion process factors (given the fact that conservation practices were in essence "phased in" over the 3 1/2 years of monitoring, trends will become more apparent with time. Nonetheless, there seems to be some encouraging relationships between conservation practices (% cover) and water quality loads. In four of six cases there was an indication that an increase in percent cover decreased

water quality loads.

- The positive effects of conservation practices in the **test** watersheds were most evident during the November through April period when the percent cover was much higher than the **control** watersheds.

- In Essex **test** sub-watershed, average and median yearly TSS concentration decreased consistently since the onset of the project. In contrast, Essex **control** sub-watershed average and median concentrations were variable. Other watersheds did not show this trend but may with time.

- It is expected that the benefits of conservation practices will become more apparent in Kettle Creek with time - especially when the effects of the **control**'s wetland areas are quantified.

- Due to the extensive sub-surface average systems in Pittock, the effect of conservation practices on surface runoff and erosion were unclear.

- Dry weather of the study period has not provided for a comparison of **test** versus **control** during years with higher than normal precipitation.

4.2.2 Microbasin Scale

- Microbasin events were variable in both timing and significance of flow. Flow events were most frequent in Kettle Creek microbasins (particularly in the **control**) and least frequent in Essex. Pittock microbasin did produce a large number of flow events but, similar to flow events at the watershed scale, most were very insignificant.

- The percent cover was higher in the **test** microbasin, particularly during the initial

November to April periods. **Control** microbasin cover was much lower for the same period.

- During high flows (in the November to April periods) the high percent cover in the **test** microbasins of Essex and Kettle Creek proved to be effective in reducing TSS loads when compared to **control** microbasins (low percent cover).

- Pittock microbasin loads were very low in both **test** and **control**. Due to the lack of moderate to high flow events, conclusions could not be drawn from the Pittock microbasins.

4.2.3 Plot Scale

- Conservation tillage resulted in significantly reduced loadings of TSS and TP in general with some exceptions. These exceptions include Post-Tillage periods wherein some cases, **test** plots produced significantly more runoff due to soil surface differences between **test** and **control** plots.

- Pre-Plant periods produced the highest loadings in all areas due to much higher TSS and TP concentrations and generally higher runoff volumes.

- Crop live and dead cover is an effective level of protection against interrill (sheet) erosion as determined in intense simulated rainfall measurements. Crop cover effectively dissipates rainfall impact energy thus minimizing particle separation from the soil matrix. Increased crop cover may also increase moisture retention, for small rainfall events. The effect of cover on rill (gully) erosion is not assessed at the plot scale.

- Rainfall simulation measurements are an effective means of evaluating conservation

- Post-Harvest measurements are of little value since in conventional systems the condition is short lived and crop residue levels are similar in **test** and **control** plots.

5.0 REFERENCES

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TABLE 2.1: SCHEDULE OF ENVIRONMENTAL MONITORING STATION INSTALLATIONS (1988 TO 1992)

		WSC		MOE	
Watershed	Sub-Watershed	Shelter Erected	Water Level Recorder Installed	ISCO Water Sampler Installed	Campbell Datalogger Meteorological Instruments*
Essex	Test	Oct. 88	Jan. 89	March 89	Data logger: Jan. 89 (no power) Soil Probes: Dec. 99
	Control	Oct. 88	Jan. 89	March 89	------
Kettle Creek	Test	June 88	July 88 Encoder - June 89	Sept. 88	Data Logger: Aug. 88 Soil Probes: Jan. 89
	Control	June 88	July 88	Sept. 88	------
Pittock	Test	June 88	July 88 Encoder - June 89	Sept. 88	Data Logger: Sept. 88 Soil Probes: Dec. 88
	Control	June 88	July 88	Sept. 88	------

*includes:

- air temperature
- rainfall rate
- water temperature
- soil temperatures (3 depths)
- relative humidity (Kettle Creek only)

TABLE 2.2: SUMMARY OF WATER QUALITY SAMPLING ACTIVITY

Year	Season[1]	Number of Events Sampled by Watershed		
		Essex	Kettle Creek	Pittock
1988	Fall	0	1	2
1989	Winter	2	1	3
	Spring	8	5	2
	Summer	2	1	2
	Fall	1	2	4
1990	Winter	2	3	2
	Spring	4	6	5
	Summer	3	3	4
	Fall	1	4	5
1991	Winter	1	1	2
	Spring	3	2	4
	Summer	0	0	2
	Fall	3	1	2
1992	Winter	4	4	2
	Spring	2	2	2
Total Interevent Samples		56	55	66

[1] Winter = January to March
Spring = April to June
Summer = July to September
Fall = October to December

TABLE 2.3: MICROBASIN FLOW MONITORING INSTALLATIONS

Station Number	Location	Hydraulic Control	Water Level Recorder	Installation Date (MM/YY)
ETB1	Essex test, drain on east side of 5th Concession	90° V-notch on culvert	Stevens F type	03/89
ETB2	Essex test, drain on east side of 5th Concession	2" Parshall flume in ditch	ISCO bubbler type, Model 1870	03/89
ECB1	Essex control, drain on east side of 2nd Concession	1" Parshall flume in ditch	ISCO bubbler type, Model 1870	03/89
ECB1	Essex control, culvert at 2nd Concession and County Road #8	90° V-notch on culvert in ditch	ISCO bubbler type, Model 1870	03/89
KTB1	Beside Madter Drain (TEST) on Vessie Farm	90° V-notch set into a berm beside drain	Stevens F type/Data Logger	05/89
KTB2	On upstream side of road culvert on 4th Concession (TEST)	90° V-notch on culvert in ditch	Stevens F type/Data Logger	04/89
KCB1	On upstream side of road culvert on 5th Concession (CONTROL)	90° V-notch on culvert in ditch	Stevens F type/Data Logger	04/89
KCB2	On downstream side of road culvert on 5th Concession at Victoria Road (CONTROL)	Weir box on culvert with 90° V-notch outlet	Stevens F type/Data Logger	04/89
PTB1	Pittock test, on west side of Highway #59 at Pioneer Seeds	90° V-notch on culvert under driveway	Montedoro-Whitney Q logger	09/89
PTB2	Pittock test, on west side of 11th Concession, south of Maplewood Road	90° V-notch on culvert in ditch	Montedero-Whitney Q logger	04/89
PCB1	Pittock control, on north side of Castle Road, near 11th Concession	90° V-notch on drop inlet	Montedoro-Whitney Q logger	04/89
PCB2	Pittock Control, on west side of 11th Concession, south of Castle Road	90° V-notch on culvert in ditch	Montedoro-Whitney Q logger	04/89

TABLE 2.4: NUMBER OF MICROBASIN EVENTS BY YEAR

Year	ECB1	ECB2	ETB1	ETB2
1989	1	1	1	1
1990	4	10	11	7
1991	1	7	4	1
1992	2	2	1	0
TOTAL	8	20	17	9
	KCB1	KCB2	KTB1	KTB2
1989	0	0	0	0
1990	28	31	10	13
1991	14	14	9	8
1992	9	9	3	4
TOTAL	51	54	22	25
	PCB1	PCB2	PTB1	PTB2
1989	0	0	0	0
1990	8	5	4	14
1991	4	4	8	8
1992	2	5	5	7
TOTAL	14	14	17	29

*Note: Due to equipment malfunction, approximately 6-8 events were not reportable during 1990.

TABLE 2.5:SEASON AND TILLAGE CONDITIONS DURING RAINFALL SIMULATION RUNS

Season	Tillage Conditions	Identification Code
Fall 1990	Post-Fall Tillage	PT90
Spring 1991	Pre-Plant	PP91
Fall 1991	Post-Harvest	PH91
Fall 1991	Post-Fall Tillage	PT91
Spring 1992	Pre-Plant	PP92

TABLE 3.1: AVERAGE AND MEDIAN TOTAL SUSPENDED SOLIDS CONCENTRATIONS (mg/L) - SWEEP PWS WATERSHEDS

	Date	Average Total Suspended Solids Concentrations (mg/L)						Median Total Suspended Solids Cocnentrations (mg/L)					
		ET	EC	KT	KC	PT	PC	ET	EC	KT	KC	PT	PC
1989	Jan. - Mar.	195.2	178.1	34.3	17.9	92.1	150.8	14.3	26.2	26.7	14.4	39	80.6
	Apr. - June	510.5	439.7	137.1	23.3	14.1	88.3	120.5	130	32.3	11.6	4	3.4
	July - Sept.	235.3	153.1	634.7	1345.1	29	11.5	102	171	437.5	693.9	9.6	2.5
	Oct. - Dec.	102.4	231.2	182.1	26.5	15.6	116.7	54	175.5	54.9	26.1	6.4	2.5
	YEAR	382.6	352.1	179.2	131.8	46.3	109.1	89.4	112.5	35	14.1	9	8.4
1990	Jan. - Mar.	102.3	79.8	363.8	45	71.1	102.3	82.4	69.9	264.5	10.9	52.8	67.3
	Apr. - June	226.8	158.8	282.4	152.5	15.9	25.2	83.4	86.2	176	58.9	4.2	3.7
	July - Sept.	313	127.9	393.5	274	18.8	12.9	99.1	94.8	159	89.2	11.5	8.1
	Oct. - Dec.	130.6	136.3	283	181.9	55.1	42.5	102	79.1	148	133	53.6	25.3
	YEAR	215.5	130.3	318.4	166.3	38.8	48.1	92.2	85.1	186.5	69.6	16.9	17
1991	Jan. - Mar.	175.6	176.4	615.7	920	316.4	436.1	110	91	420	253.5	55.3	150
	Apr. - June	317.8	237.6	104.9	138.8	141.7	352.9	96.5	103.2	43.6	125	17.5	13.9
	July - Sept.	0	0	861	0	21.1	44.5	0	0	504.5	0	13.5	6.1
	Oct. - Dec.	93.3	54.9	34.4	42.2	8.1	5.3	59.3	15.6	33.4	24.2	4.9	3.7
	YEAR	204.7	149.3	225.1	403.1	137.1	222.4	87.4	70.8	46.7	128	16.7	7.6
1992	Jan. - Mar.	154.9	180.9	277.4	75.9	7.5	6.9	142.5	104.5	72.1	28.5	5.8	6.5
	Apr. - June	263.6	252.9	1034.5	651.1	61.6	39.9	151	115	132	63.7	3.3	3.8
	6 months	192.7	201.7	498.3	293.3	30.5	21.5	145.5	103	87	48.7	5.3	5.5

ET - Essex Test Subwatershed
EC - Essex Control Subwatershed
KT - Kettle Creek Test Subwatershed
KC - Kettle Creek Control Subwatershed
PT - Pittock Test Subwatershed
PC - Pittock Control Subwatershed

TABLE 3.2: AVERAGE AND MEDIAN TOTAL PHOSPHORUS CONCENTRATIONS (mg/L) - SWEEP PWS WATERSHEDS

		Average Total Phosphorus Concentrations (mg/L)						Median Phosphorus Concentrations (mg/L)					
	Date	ET	EC	KT	KC	PT	PC	ET	EC	KT	KC	PT	PC
1989	Jan. - Mar.	0.46	0.542	0.199	0.131	0.363	0.809	0.103	0.125	0.18	0.13	0.315	0.61
	Apr. - June	0.909	0.645	0.324	0.275	14.1	0.249	0.52	0.368	0.13	0.18	0.15	0.05
	July - Sept.	0.458	0.209	1.357	2.348	29	0.126	0.28	0.23	1.12	1.79	0.29	0.07
	Oct. - Dec.	0.278	0.341	0.598	0.736	15.6	0.476	0.17	0.28	0.33	0.35	0.2	0.04
	YEAR	0.69	0.625	0.46	0.461	0.313	0.499	0.316	0.315	0.18	0.18	0.21	0.17
1990	Jan. - Mar.	0.382	0.321	0.661	0.256	0.564	1.435	0.409	0.34	0.48	0.195	0.44	0.97
	Apr. - June	0.605	0.493	0.91	0.38	0.129	0.141	0.41	0.425	0.34	0.24	0.06	0.06
	July - Sept.	0.748	0.402	0.861	0.674	0.297	0.176	0.42	0.405	0.574	0.35	0.18	0.051
	Oct. - Dec.	0.387	0.38	0.903	0.637	0.176	0.217	0.355	0.348	0.582	0.565	0.101	0.131
	YEAR	0.573	0.415	0.916	0.504	0.559	0.509	0.417	0.368	0.44	0.296	0.147	0.141
1991	Jan. - Mar.	0.524	0.546	1.193	1.39	0.791	1.198	0.525	0.273	0.837	0.783	0.32	0.77
	Apr. - June	1.031	0.389	0.3	0.512	0.472	0.799	0.315	0.266	0.099	0.348	0.183	0.084
	July - Sept.	0	0	1.298	0	0.329	0.109	0	0	1.02	0	0.26	0.031
	Oct. - Dec.	0.215	0.212	0.185	0.191	0.321	0.097	0.236	0.142	0.195	0.149	0.227	0.031
	YEAR	0.688	0.339	0.519	0.793	0.472	0.581	0.258	0.166	0.213	0.359	0.22	0.063
1992	Jan. - Mar.	0.521	0.636	0.505	0.259	0.11	0.126	0.49	0.535	0.238	0.196	0.109	0.115
	Apr. - June	0.596	0.782	1.917	0.15	0.201	0.182	0.48	0.548	0.35	0.121	0.049	0.084
	6 Months	0.544	0.678	0.92	0.233	0.15	0.148	0.49	0.525	0.287	0.176	0.103	0.102

ET - Essex Test Subwatershed
EC - Essex Control Subwatershed
KT - Kettle Creek Test Subwatershed
KC - Kettle Creek Control Subwatershed
PT - Pittock Test Subwatershed
PC - Pittock Control Subwatershed

TABLE 3.3: AVERAGE AND MEDIAN FILTERED REACTIVE PHOSPHOROUS CONCENTRATIONS (mg/L) - SWEEP PWS WATERSHEDS

	Date	Average Filtered Reactive Phosphorus Concentrations (mg/L)						Median Filtered Reactive Phosphorus Concentrations (mg/L)					
		ET	EC	KT	KC	PT	PC	ET	EC	KT	KC	PT	PC
1989	Jan. - Mar.	0.024	0.018	0.058	0.023	0.096	0.338	0.117	0.008	0.042	0.013	0.09	0.205
	Apr. - June	0.039	0.028	0.026	0.147	0.027	0.02	0.033	0.02	0.02	0.098	0.01	0.005
	July - Sept.	0.049	0.007	0.037	0.085	0.05	0.018	0.05	0.005	0.025	0.085	0.03	0.005
	Oct. - Dec.	0.038	0.027	0.09	0.393	0.202	0.108	0.03	0.015	0.07	0.14	0.12	0.01
	YEAR	0.038	0.025	0.044	0.136	0.116	0.157	0.03	0.014	0.035	0.09	0.06	0.04
1990	Jan. - Mar.	0.068	0.043	0.046	0.062	0.254	0.713	0.05	0.035	0.04	0.06	0.19	0.44
	Apr. - June	0.033	0.009	0.046	0.058	0.053	0.065	0.03	0.005	0.03	0.041	0.035	0.028
	July - Set.	0.102	0.085	0.282	0.106	0.153	0.082	0.07	0.049	0.108	0.092	0.114	0.015
	Oct. - Dec.	0.058	0.051	0.08	0.117	0.074	0.074	0.021	0.023	0.098	0.102	0.114	0.067
	YEAR	0.081	0.044	0.1	0.083	0.116	0.365	0.041	0.021	0.047	0.07	0.062	0.07
1991	Jan. - Mar.	0.042	0.019	0.051	0.048	0.088	0.157	0.028	0.025	0.054	0.043	0.09	0.16
	Apr. - June	0.073	0.035	0.052	0.177	0.05	0.038	0.056	0.007	0.028	0.125	0.029	0.021
	July - Sept.	0	0	0.065	0	0.122	0.017	0	0	0.06	0	0.147	0.008
	Oct. - Dec.	0.091	0.038	0.072	0.086	0.15	0.078	0.088	0.041	0.071	0.079	0.137	0.019
	YEAR	0.075	0.034	0.061	0.11	0.089	0.072	0.06	0.019	0.057	0.071	0.065	0.021
1992	Jan. - Mar.	0.035	0.036	0.061	0.064	0.054	0.037	0.022	0.024	0.059	0.058	0.052	0.028
	Apr. - June	0.025	0.033	0.028	0.054	0.099	0.085	0.034	0.031	0.031	0.044	0.048	0.06
	6 Months	0.031	0.034	0.051	0.062	0.073	0.057	0.023	0.026	0.046	0.058	0.052	0.04

ET - Essex Test Subwatershed
EC - Essex Control Subwatershed
KT - Kettle Creek Test Subwatershed
KC - Kettle Creek Control Subwatershed
PT - Pittock Test Subwatershed
PC - Pittock Control Subwatershed

TABLE 3.4: SUMMARY OF REGRESSION ANALYSIS COMPARING AUTOMATED ISCO SAMPLE CONCENTRATIONS AND MANUALLY COLLECTED SAMPLE CONCENTRATIONS

Sub-Watershed	Water Quality Parameter	Number of Observations	r^2	Slope	Y-Intercept
Essex Test	TSS	36	0.83	0.94	-4.47
	TP	37	0.90	0.95	-0.00
	FRP	35	0.29	0.29	-0.03
Essex Control	TSS	37	0.75	0.73	-1.26
	TP	38	0.60	0.63	0.41
	FRP	35	0.62	0.65	0.03
Kettle Creek Test	TSS	30	0.95	0.79	3.18
	TP	30	0.97	1.02	-0.04
	FRP	30	0.99	1.80	-0.03
Kettle Creek Control	TSS	26	0.93	0.98	-6.67
	TP	26	0.94	1.00	-0.28
	FRP	25	0.35	1.66	-0.00
Pittock Test	TSS	41	0.75	0.70	7.95
	TP	41	0.95	0.89	-0.56
	FRP	40	0.77	0.96	0.03
Pittock Control*	TSS	35	0.92	0.94	8.60
	TP	35	0.97	1.01	.008
	FRP	34	0.79	0.72	0.03

Note: The manually collected samples were the dependent variable used in the regression analysis.

* One anomalous value was excluded from the regression analysis.

Table 3.5: Summary of 1989 to 1992 Total Suspended Solids Loadings

Total Suspended Solids (tonnes)

Sub-Watershed	Area (ha)	1989 Season* J-M	A-J	J-S	O-D	1989 Total	1990 Season* J-M	A-J	J-S	O-D	1990 Total	1991 Season* J-M	A-J	J-S	O-D	1991 Total	1992 Season* J-M	A-J	1992 Total
Essex Test	435	6.49	208.40	42.47	1.93	259.29	87.74	32.38	118.45	145.09	383.66	57.20	65.51	0.00	12.29	135.00	123.60	41.84	165.44
Essex Control	281	7.16	133.80	43.84	2.09	186.89	58.12	19.14	83.68	93.61	254.55	37.16	31.17	0.00	2.89	71.22	75.96	23.65	99.61
Kettle Creek Test	410	16.94	18.41	1.10	5.65	42.11	512.50	63.45	113.01	224.00	912.96	119.22	18.92	0.00	3.88	142.02	167.60	132.32	299.92
Kettle Creek Control	354	5.93	2.14	3.41	0.51	11.99	41.40	19.06	43.82	132.40	181.31	136.68	10.53	0.00	0.77	147.98	38.16	114.03	152.19
Pittock Test	359	12.45	7.08	0.01	0.33	19.87	21.37	1.88	1.43	28.35	53.03	90.13	12.95	0.01	0.10	103.19	4.08	8.58	12.66
Pittock Control	384	14.04	4.04	0.04	1.07	19.18	19.82	1.56	0.48	13.74	35.60	149.17	14.23	0.10	0.01	163.50	1.88	5.07	6.95

Unit Area Total Suspended Solids (tonnes/ha)

Sub-Watershed	Area (ha)	1989 Season* J-M	A-J	J-S	O-D	1989 Total	1990 Season* J-M	A-J	J-S	O-D	1990 Total	1991 Season* J-M	A-J	J-S	O-D	1991 Total	1992 Season* J-M	A-J	1992 Total
Essex Test	435	0.015	0.479	0.098	0.004	0.60	0.202	0.074	0.272	0.334	0.88	0.131	0.151	0.000	0.028	0.31	0.284	0.096	0.38
Essex Control	281	0.025	0.476	0.156	0.007	0.67	0.207	0.068	0.298	0.333	0.91	0.132	0.111	0.000	0.010	0.25	0.270	0.084	0.35
Kettle Creek Test	410	0.041	0.045	0.003	0.014	0.10	1.250	0.155	0.276	0.546	2.23	0.291	0.046	0.000	0.009	0.35	0.409	0.323	0.73
Kettle Creek Control	354	0.017	0.006	0.010	0.001	0.03	0.117	0.054	0.124	0.374	0.51	0.386	0.030	0.000	0.002	0.42	0.108	0.322	0.43
Pittock Test	359	0.035	0.020	0.000	0.001	0.06	0.060	0.005	0.004	0.079	0.15	0.251	0.036	0.000	0.000	0.29	0.011	0.024	0.04
Pittock Control	384	0.037	0.011	0.000	0.003	0.05	0.052	0.004	0.001	0.036	0.09	0.388	0.037	0.000	0.000	0.43	0.005	0.013	0.02

* Note: Seasons are identified as:

January - March (J-M)
April - June (A-J)
July - September (J-S)

Table 3.6: Summary of 1989 to 1992 Total Phosphorous Loadings

Total Phosphorous (kg)

Sub-Watershed	Area (ha)	1989 Season* J-M	A-J	J-S	O-D	1989 Total	1990 Season* J-M	A-J	J-S	O-D	1990 Total	1991 Season* J-M	A-J	J-S	O-D	1991 Total	1992 Season* J-M	A-J	1992 Total
Essex Test	435	31.0	455.7	88.5	6.7	581.9	367.5	116.5	385.0	392.2	1261.2	178.2	245.7	0.0	37.2	461.1	428.6	110.3	538.9
Essex Control	281	27.8	263.5	77.0	4.0	372.3	250.0	70.1	262.5	344.4	927.0	123.5	97.6	0.0	11.3	232.4	301.1	84.0	385.1
Kettle Creek Test	410	53.2	53.7	2.2	23.3	132.4	1187.0	155.5	316.4	550.8	2209.7	289.5	44.6	0.0	24.2	358.4	426.5	255.1	681.6
Kettle Creek Control	354	42.1	20.4	15.8	10.1	88.4	380.3	80.5	157.2	453.9	1071.9	317.5	39.4	0.0	4.6	361.5	125.5	105.3	230.8
Pittock Test	359	86.6	57.5	0.1	7.8	152.0	206.8	14.4	10.4	122.3	353.9	302.2	53.0	0.2	4.1	359.4	44.4	40.5	85.0
Pittock Control	384	116.0	40.6	0.6	6.1	163.4	335.8	26.7	4.7	86.3	453.6	443.5	62.5	0.4	0.1	506.6	24.0	35.2	59.2

Unit Area Total Phosphorous (kg/ha)

Sub-Watershed	Area (ha)	1989 Season* J-M	A-J	J-S	O-D	1989 Total	1990 Season* J-M	A-J	J-S	O-D	1990 Total	1991 Season* J-M	A-J	J-S	O-D	1991 Total	1992 Season* J-M	A-J	1992 Total
Essex Test	435	0.07	1.05	0.20	0.02	1.34	0.84	0.27	0.89	0.90	2.90	0.41	0.56	0.00	0.09	1.06	0.99	0.25	1.24
Essex Control	281	0.10	0.94	0.27	0.01	1.32	0.89	0.25	0.93	1.23	3.30	0.44	0.35	0.00	0.04	0.83	1.07	0.30	1.37
Kettle Creek Test	410	0.13	0.13	0.01	0.06	0.32	2.90	0.38	0.77	1.34	5.39	0.71	0.11	0.00	0.06	0.87	1.04	0.62	1.66
Kettle Creek Control	354	0.12	0.06	0.04	0.03	0.25	1.07	0.23	0.44	1.28	3.03	0.90	0.11	0.00	0.01	1.02	0.35	0.30	0.65
Pittock Test	359	0.24	0.16	0.00	0.02	0.42	0.58	0.04	0.03	0.34	0.99	0.84	0.15	0.00	0.01	1.00	0.12	0.11	0.24
Pittock Control	384	0.30	0.11	0.00	0.02	0.43	0.87	0.07	0.01	0.22	1.18	1.15	0.16	0.00	0.00	1.32	0.06	0.09	0.15

* Note: Seasons are identified as:

January - March (J-M)
April - June (A-J)
July - September (J-S)
October - December (O-D)

Table 3.7: Summary of 1989 to 1992 Filtered Reactive Phosphorous Loadings

Total Filtered Reactive Phosphorous (kg)

Sub-Watershed	Area (ha)	1989 Season* J-M	A-J	J-S	O-D	1989 Total	1990 Season* J-M	A-J	J-S	O-D	1990 Total	1991 Season* J-M	A-J	J-S	O-D	1991 Total	1992 Season* J-M	A-J	1992 Total
Essex Test	435	2.23	9.83	1.73	0.96	14.75	15.62	9.01	23.43	33.13	81.19	10.12	20.53	0.00	9.82	40.47	20.91	4.36	25.27
Essex Control	281	1.58	6.46	1.32	0.16	9.52	16.69	3.70	7.85	25.56	53.80	2.93	3.17	0.00	0.96	7.06	12.33	3.40	15.73
Kettle Creek Test	410	6.92	5.20	0.06	3.17	15.35	39.59	14.96	36.73	42.44	133.72	19.84	4.15	0.00	9.44	33.43	36.86	5.00	41.86
Kettle Creek Control	354	8.83	5.77	1.56	4.12	20.27	55.40	15.03	32.41	41.36	144.20	26.81	10.47	0.00	2.28	39.56	32.39	10.79	43.18
Pittock Test	359	18.04	11.42	0.01	3.81	33.29	73.20	4.26	2.78	22.06	102.30	21.43	6.39	0.03	1.56	29.42	18.26	13.54	31.80
Pittock Control	384	40.54	13.77	0.13	1.21	55.65	148.80	11.67	2.34	32.14	194.95	51.72	10.84	0.05	0.06	62.67	6.80	12.83	19.63

Unit Area Filtered Reactive Phosphorous (kg/ha)

Sub-Watershed	Area (ha)	1989 Season* J-M	A-J	J-S	O-D	1989 Total	1990 Season* J-M	A-J	J-S	O-D	1990 Total	1991 Season* J-M	A-J	J-S	O-D	1991 Total	1992 Season* J-M	A-J	1992 Total
Essex Test	435	0.005	0.023	0.004	0.002	0.034	0.036	0.021	0.054	0.076	0.187	0.023	0.047	0.000	0.023	0.093	0.048	0.010	0.058
Essex Control	281	0.006	0.023	0.005	0.001	0.034	0.059	0.013	0.028	0.091	0.191	0.010	0.011	0.000	0.003	0.025	0.044	0.012	0.056
Kettle Creek Test	410	0.017	0.013	0.000	0.008	0.037	0.097	0.036	0.090	0.104	0.326	0.048	0.010	0.000	0.023	0.082	0.090	0.012	0.102
Kettle Creek Control	354	0.025	0.016	0.004	0.012	0.057	0.156	0.042	0.092	0.117	0.407	0.076	0.030	0.000	0.006	0.112	0.091	0.030	0.122
Pittock Test	359	0.050	0.032	0.000	0.011	0.093	0.204	0.012	0.008	0.061	0.285	0.060	0.018	0.000	0.004	0.082	0.051	0.038	0.089
Pittock Control	384	0.106	0.036	0.000	0.003	0.145	0.388	0.030	0.006	0.084	0.508	0.135	0.028	0.000	0.000	0.163	0.018	0.033	0.051

* Note: Seasons are identified as:

January - March (J-M)
April - June (A-J)
July - September (J-S)
October - December (O-D)

Table 3.8: Generalized PWS Cover (% Live and Dead) Patterns by Month and Crop-Tillage System

Month		Jan	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
Corn:	Conventional	7.5	7.5	7.5	7.5	15	40	80	100	100	70	8	8
	Reduced Till	31	29	26	23	30	60	85	100	100	75	33	32
	No Till	87	85	82	80	85	90	95	100	100	100	88	87
Winter Wheat:	Conventional	8	8	8	10	55	100	80	7	7	7	8	8
	Reduced Till	35	35	35	45	70	100	85	38	38	35	35	35
	No Till	88	85	80	85	90	100	90	80	80	85	90	90
Beans:	Conventional	9	9	9	9	15	35	65	80	100	50	9	9
	Reduced Till	30	30	30	30	35	50	80	90	100	60	30	30
	No Till	75	75	70	69	75	80	90	95	100	90	80	80
Spring Grain:	Conventional	8	8	8	8	20	45	80	100	100	8	8	8
	Reduced Till	28	28	28	28	35	55	90	100	100	28	28	28
	No Till	90	89	88	87	95	100	100	100	100	92	92	91
Fallow		5	5	5	5	5	5	5	5	5	5	5	5
Bush/Buildings		70	70	70	80	95	95	95	95	95	95	80	70
Idle/Pasture		95	95	95	95	95	95	95	95	95	95	95	95

Table 3.9: Watershed Scale Average Cover (% Live & Dead) By Season

		ESSEX		KETTLE CREEK		PITTOCK	
		Test	Control	Test	Control	Test	Control
1989	Winter	22.5	20.2	31.9	28.7	35.5	34.1
	Spring	37.6	37.1	44.6	43.8	48.7	46.1
	Summer	81.9	79.2	85.7	78.4	89.2	92.8
	Fall	33.9	31.7	44.5	38.4	46.8	47.8
	1989 Average	44.0	42.1	51.7	47.3	55.1	55.2
1990	Winter	24.6	18.2	42.4	28.6	37.8	25.5
	Spring	41.9	37.5	54.4	44.5	47.8	34.0
	Summer	77.7	77.1	87.4	84.3	87.9	84.3
	Fall	34.6	30.1	53.4	41.0	49.6	38.7
	1990 Average	44.7	40.7	59.4	49.6	55.8	45.6
1991	Winter	28.0	17.9	48.2	24.2	31.7	29.9
	Spring	37.8	32.1	59.1	36.4	43.9	44.1
	Summer	87.5	85.3	89.0	90.9	90.7	89.9
	Fall	40.6	32.6	58.3	39.9	45.4	43.0
	1991 Average	48.5	42.0	63.7	47.9	52.9	51.7
1992	Winter	30	19	50	27	35	30

TABLE 3.10: REGRESSION ANALYSIS COEFFICIENTS RELATING WATERSHED LOADS TO FLOW AND PERCENT COVER

Watershed	TSS				TP				FRP			
	I	F	C	R^2	I	F	C	R^2	I	F	C	R^2
Essex Test	-0.284	0.146	0.010	0.97	-0.637	0.431	0.027	0.93	--0.072	0.029	0.003	0.97
Essex Control	0.743	0.104	-0.036	0.58	8.02	0.149	-0.379	0.66	0.437	0.007	-0.021	0.99
Kettle Creek Test	1.57	1.075	-0.076	0.99	3.60	2.44	-0.172	0.99	-0.077	0.030	0.002	0.87
Kettle Creek Control	3.50	0.059	-0.123	0.69	5.81	0.390	-0.211	0.28	-0.120	0.071	0.003	0.99
Pittock Test	0.241	0.152	-0.012	0.64	-1.57	0.579	0.028	0.49	-1.31	0.090	0.035	0.99
Pittock Control	-0.621	0.230	0.015	0.98	0.406	0.612	-0.020	0.72	0.918	0.049	-0.026	0.81

I = intercept
F = flow coefficient
C = cover coefficient

TABLE 3.11: SUMMARY OF AVERAGE AND MEDIAN MICROBASIN TSS CONCENTRATIONS

	ETB1			ETB2			ECB1			ECB2		
	N	Avg.	Median	N	Avg.	Median	N	Avg.	Median	N	Avg.	Median
Essex 1989	40	510.1	101.0	38	693.6	151.0	28	347.4	180.0	35	201.5	104.0
Essex 1990	58	330.6	141.0	41	152.9	76.0	54	98.6	50.5	49	241.4	86.0
Essex 1991	21	328.1	75.0	18	139.1	29.5	6	31.7	7.0	27	86.5	43.0
Essex 1992	17	198.2	48.0	15	30.1	22.4	8	152.4	51.5	18	250.3	112.5

	KTB1			KTB2			KCB1			KCB2		
	N	Avg.	Median	N	Avg.	Med.	N	Avg.	Med.	N	Avg.	Med.
Kettle Creek 1989	0	0.0	0.0	0	0.0	0.0	3	198.0	126.0	11	629.6	52.0
Kettle Creek 1990	39	294.0	240.0	59	575.9	184.0	61	410.7	380.0	97	151.4	80.0
Kettle Creek 1991	17	734.6	460.0	24	437.8	180.5	26	435.7	350.0	38	235.8	90.5
Kettle Creek 1992	16	337.4	35.5	19	275.9	26.0	27	845.4	48.0	28	147.9	21.5

	PTB1			PTB2			PCB1			PCB2		
	N	Avg.	Median	N	Avg.	Med.	N	Avg.	Med.	N	Avg.	Med.
Pittock 1989	0	0.0	0.0	0	0.0	0.0	1	1100.0	0.0	1	2.5	0.0
Pittock 1990	52	28.2	12.0	37	50.8	30.0	19	182.1	74.0	5	81.2	40.0
Pittock 1991	32	22.9	8.5	20	674.3	298.0	9	106.0	38.0	7	67.7	62.0
Pittock 1992	23	15.0	6.0	23	62.2	8.0	5	25.2	18.0	9	81.1	38.0

N - number of samples
NA - not available
X - only one sample collected

TABLE 3.12: SUMMARY OF AVERAGE AND MEDIAN MICROBASIN TP CONCENTRATIONS

	ETB1			ETB2			ECB1			ECB2		
	N	Avg.	Median	N	Avg.	Med.	N	Avg.	Med.	N	Avg.	Med.
Essex 1989	40	0.399	0.245	38	0.383	0.155	28	0.353	0.236	35	0.186	0.135
Essex 1990												
Essex 1991	21	0.416	0.179	18	0.203	0.075	6	0.142	0.117	27	0.130	0.069
Essex 1992	17	0.271	0.107	15	0.085	0.082	8	0.287	0.245	18	0.342	0.285

	KTB1			KTB2			KCB1			KCB2		
	N	Avg.	Median	N	Avg.	Med.	N	Avg.	Med.	N	Avg.	Med.
Kettle Creek 1989	0	NA	NA	0	NA	NA	3	0.587	0.410	11	0.813	0.510
Kettle Creek 1990	39	1.064	0.920	59	1.387	0.600	61	0.908	0.800	97	0.452	0.280
Kettle Creek 1991	17	2.055	1.350	24	1.125	0.525	26	0.932	0.230	38	0.665	0.340
Kettle Creek 1992	16	0.984	0.255	19	0.582	0.172	27	5.094	0.350	28	0.485	0.184

	PTB1			PTB2			PCB1			PCB2		
	N	Avg.	Median	N	Avg.	Med.	N	Avg.	Med.	N	Avg.	Med.
Pittock 1989	0	NA	NA	0	NA	NA	1	NA	NA	1	NA	NA
Pittock 1990	52	0.259	0.197	37	0.224	0.195	19	0.316	0.200	5	0.357	0.191
Pittock 1991	32	0.251	0.100	20	1.467	0.340	9	0.418	0.190	6	0.225	0.265
Pittock 1992	23	0.104	0.111	23	0.261	0.168	5	0.080	0.070	9	0.141	0.107

N - number of samples
NA - not available
X - only one sample collected

TABLE 3.13: NUMBER OF MICROBASIN EVENTS BY YEAR

Year	ECB1	ECB2	ETB1	ETB2
1989	1	1	1	1
1990	4	10	11	7
1991	1	7	4	1
1992	2	2	1	0
TOTAL	8	20	17	9
	KCB1	KCB2	KTB1	KTB2
1989	0	0	0	0
1990	28	31	10	13
1991	14	14	9	8
1992	9	9	3	4
TOTAL	51	54	22	25
	PCB1	PCB2	PTB1	PTB2
1989	0	0	0	0
1990	8	5	4	14
1991	4	4	8	8
1992	2	5	5	7
TOTAL	14	14	17	29

*Note: Due to equipment malfunction, approximately 6-8 events were not reportable during 1990.

Table 3.14 Selected Essex Microbasin Unit Area Flow and Load Events

Date (Month Day Year)		ECB1 Flow	ECB1 TSS Load	ECB1 TP Load	ECB2 Flow	ECB2 TSS Load	ECB2 TP Load	ETB1 Flow	ETB1 TSS Load	ETB1 TP Load	ETB2 Flow	ETB2 TSS Load	ETB2 TP Load
April 10	1990	2.90	1.829	0.0005	---	---	---	20.57	4.849	0.0082	0.53	0.082	0.0001
April 11	1990	0.48	0.488	0.0002	1.83	1.159	0.0002	0.48	1.132	0.0002	0.89	0.049	0.0000
April 12	1990	---	---	---	1.22	0.435	0.0001	---	---	---	---	---	---
Event Total		3.39	2.317	0.0007	3.05	1.594	0.0003	21.04	5.981	0.0085	1.42	0.131	0.0001
May 16	1990	---	---	---	23.84	19.493	0.0275	23.96	9.075	0.0135	10.85	0.934	0.0013
May 17	1990	---	---	---	5.22	1.000	0.0015	3.81	0.604	0.0011	2.66	0.148	0.0001
May 18	1990	---	---	---	0.26	0.007	0.0145	---	---	---	---	---	---
Event Total		0.00	0.000	0.0000	29.32	20.500	0.0435	27.77	9.679	0.0147	13.51	1.082	0.0014
September 19	1990	10.15	2.390	0.0054	227.61	1050.725	1.2971	18.13	5.698	0.0088	92.62	14.410	0.0290
September 20	1990	0.00	0.012	0.0000	41.74	47.536	0.0646	0.00	0.057	0.0001	3.36	0.246	0.0003
September 21	1990	---	---	---	0.73	0.029	0.0000	---	---	---	---	---	---
Event Total		10.15	2.402	0.0054	270.08	1098.290	1.3618	18.13	5.755	0.0090	95.98	14.656	0.0293
November 18	1991	---	---	---	0.37	0.014	0.00004	0.14	0.002	0.00004	---	---	---
November 19	1991	---	---	---	0.44	0.022	0.0001	1.15	0.019	0.0001	---	---	---
November 20	1991	0.13			5.45	0.319	0.0005	10.40	1.396	0.0022	6.38	0.082	0.0003
November 21	1991	---	---	---	1.38	0.065	0.0001	2.04	0.019	0.0001	0.89	0.016	0.0001
Event Total		0.13	0.000	0.0000	7.64	0.420	0.0008	13.72	1.436	0.0025	7.26	0.098	0.0004
March 25	1992	---	---	---	4.96	0.674	0.0012	3.53	0.094	0.00002	---	---	---
March 26	1992	15.49	6.427	0.0074	19.93	3.094	0.0052	20.00	0.698	0.0014	---	---	---
March 27	1992	12.44	2.280	0.0046	30.58	7.899	0.0122	15.70	0.491	0.0010	---	---	---
March 28	1992	0.75	0.244	0.0002	1.57	0.065	0.0013	1.09	0.019	0.0001	---	---	---
Event Total		28.67	8.951	0.0121	57.03	11.732	0.0199	40.31	1.302	0.0025	---	---	---

Note: Unit Area Flows are given in cubic metres per day
Unit Area Loads are given in kg per day

Table 3.15 Selected Kettle Creek Microbasin Unit Area Flow and Load Events

Date (Month Day Year)		KCB1 Flow	KCB1 TSS Load	KCB1 TP Load	KCB2 Flow	KCB2 TSS Load	KCB2 TP Load	KTB1 Flow	KTB1 TSS Load	KTB1 TP Load	KTB2 Flow	KTB2 TSS Load	KTB2 TP Load
March 12	1990	0.00	0.000	0.0000	0.00	0.000	0.0000	0.00	0.000	0.0000	7.33	1.235	0.0034
March 13	1990	16.94	3.082	0.0058	0.00	0.000	0.0000	0.00	0.000	0.0000	0.00	0.039	0.0002
March 14	1990	3.44	0.259	0.0004	15.90	0.805	0.0034	0.00	0.000	0.0000	0.00	0.020	0.0001
March 15	1990	2.04	0.118	0.0002	15.54	0.585	0.0024	0.00	0.000	0.0000	0.00	0.000	0.0000
March 16	1990	4.40	0.424	0.0007	39.76	4.000	0.0178	0.00	0.000	0.0000	0.42	0.039	0.0001
March 17	1990	1.78	0.106	0.0001	7.02	0.171	0.0007	0.00	0.000	0.0000	0.00	0.000	0.0000
Event Total		28.59	3.988	0.0071	78.22	5.561	0.0242	0.00	0.000	0.0000	7.76	1.333	0.0038
April 10	1990	0.00	0.012	0.0000	39.76	6.244	0.0283	0.00	0.000	0.0000	12.84	2.275	0.0063
April 11	1990	0.97	0.047	0.0001	15.02	0.683	0.0029	0.00	0.000	0.0000	0.49	0.020	0.0001
April 12	1990	0.00	0.000	0.0000	1.40	0.024	0.0001	0.00	0.000	0.0000	0.00	0.000	0.0000
Event Total		0.97	0.059	0.0001	56.19	6.951	0.0313	0.00	0.000	0.0000	13.34	2.294	0.0064
May 16	1990	27.88	6.694	0.0139	45.12	5.610	0.0251	117.38	32.154	0.1754	7.49	1.569	0.0042
May 17	1990	92.94	3.776	0.0951	53.90	5.439	0.0241	89.85	24.769	0.1355	9.88	3.020	0.0073
May 18	1990	1.10	0.071	0.0001	3.95	0.098	0.0004	0.00	0.000	0.0000	0.00	0.000	0.0000
Event Total		121.92	10.541	0.1090	102.98	11.146	0.0496	207.23	56.923	0.3109	17.37	4.588	0.0115
November 5	1990	421.88	256.471	0.7318	98.29	17.659	0.0807	1064.92	352.308	2.2462	164.31	145.098	0.2824
November 6	1990	88.82	38.471	0.0981	74.63	8.366	0.0373	0.00	0.000	0.0000	12.35	2.412	0.0065
November 7	1990	0.00	0.000	0.0000	9.49	0.268	0.0011	0.00	0.000	0.0000	0.00	0.000	0.0000
November 8	1990	0.00	0.000	0.0000	2.37	0.024	0.0001	0.00	0.000	0.0000	0.00	0.000	0.0000
Event Total		510.71	294.941	0.8299	184.79	26.317	0.1193	1064.92	352.308	2.2462	176.67	147.510	0.2889
April 19	1991	0.00	0.000	0.0000	0.88	0.049	0.0002	0.00	0.000	0.0000	0.00	0.000	0.0000
April 20	1991	106.71	14.353	0.0408	23.71	1.707	0.0077	128.62	54.308	0.1892	8.20	1.941	0.0050
April 21	1991	4.07	0.094	0.0006	8.61	0.366	0.0019	0.00	0.000	0.0000	0.00	0.000	0.0000
April 22	1991	0.68	0.009	0.0000	0.00	0.000	0.0000	0.00	0.000	0.0000	0.00	0.000	0.0000
Event Total		111.45	14.456	0.0414	33.20	2.122	0.0097	128.62	54.308	0.1892	8.20	1.941	0.0050
April 23	1992	2.84	1.400	0.0051	2.54	0.098	0.0007	0.17	0.462	0.0000	0.21	0.000	0.0000
April 24	1992	129.53	1305.882	2.9412	355.37	48.049	0.4805	167.54	1343.077	2.5846	344.31	0.034	0.0000
April 25	1992	0.30	0.012	0.0000	15.37	0.268	0.0019	0.00	0.000	0.0000	0.00	0.000	0.0000
Event Total		132.66	1307.294	2.9463	373.27	48.415	0.4830	167.70	1343.538	2.5846	344.53	0.034	0.0000

Note: Unit Area Flows are given in cubic metres per day/event
Unit Area Loads are given in kg per day/event

Table 3.16 Selected Pittock Microbasin Unit Area Flow and Load Events

Date (Month Day Year)		PCB1 Flow	PCB1 TSS Load	PCB1 TP Load	PCB2 Flow	PCB2 TSS Load	PCB2 TP Load	PTB1 Flow	PTB1 TSS Load	PTB1 TP Load	PTB2 Flow	PTB2 TSS Load	PTB2 TP Load
March 9	1990	0.34	0.047	0.0001	0.00	0.000	0.0000	20.20	0.774	0.0050	0.00	0.000	0.0000
March 10	1990	0.00	0.000	0.0000	0.00	0.000	0.0000	0.00	0.000	0.0000	34.46	0.939	0.0061
March 11	1990	0.00	0.000	0.0000	0.00	0.000	0.0000	0.00	0.000	0.0000	55.64	1.514	0.0099
March 12	1990	0.56	0.078	0.0001	2.59	0.079	0.0008	0.00	0.000	0.0000	34.64	0.982	0.0059
Event Total		0.90	0.125	0.0002	2.59	0.079	0.0008	20.20	0.774	0.0050	124.75	3.436	0.0219
November 5	1990	1.46	0.156	0.0003	12.11	0.305	0.0048	1.87	0.044	0.0005	55.39	1.468	0.0101
November 6	1990	0.00	0.000	0.0000	0.79	0.025	0.0001	0.00	0.000	0.0000	98.57	2.646	0.0177
November 7	1990	0.00	0.000	0.0000	0.00	0.000	0.0000	0.00	0.000	0.0000	11.18	0.332	0.0018
Event Total		1.46	0.156	0.0003	12.90	0.330	0.0050	1.87	0.044	0.0005	165.14	4.446	0.0297
March 6	1991	0.87	0.047	0.0002	28.59	0.887	0.0036	0.63	0.004	0.0001	48.04	0.017	0.0225
March 7	1991	0.00	0.000	0.0000	7.20	0.172	0.0009	4.27	0.149	0.0003	22.00	0.005	0.0080
Event Total		2.34	0.203	0.0005	48.70	1.389	0.0095	6.77	0.198	0.0008	235.18	4.468	0.0602
March 27	1991	0.03	0.008	0.0000	71.41	3.581	0.0100	78.91	0.018	0.0069	95.04	35.821	0.0457
March 28	1991	0.00	0.000	0.0000	75.08	3.493	0.0103	11.73	0.001	0.0012	76.18	23.464	0.0331
March 29	1991	0.00	0.000	0.0000	0.00	0.000	0.0000	0.00	0.000	0.0000	3.68	1.250	0.0007
Event Total		0.03	0.008	0.0000	146.48	7.074	0.0202	90.65	0.019	0.0081	174.89	60.536	0.0795
April 16	1992	0.39	0.016	0.0000	0.00	0.000	0.0000	0.00	0.000	0.0000	0.00	0.000	0.0000
April 17	1992	0.00	0.000	0.0000	1.13	0.054	0.0001	5.04	0.036	0.0005	38.50	0.414	0.0061
April 18	1992	0.00	0.000	0.0000	0.00	0.000	0.0000	4.48	0.032	0.0004	8.39	0.500	0.0029
April 19	1992	0.00	0.000	0.0000	0.00	0.000	0.0000	0.00	0.000	0.0000	0.22	0.082	0.0018
Event Total		0.39	0.016	0.0000	1.13	0.054	0.0001	9.52	0.069	0.0010	47.11	0.996	0.0108

Note: Unit Area Flows are given in cubic metres per day/event
Unit Area Loads are given in kg per day/event

Table 3.17: Characteristics of Rainfall Simulation Sites

SEASON	SITE	CROP	MANAGEMENT PRACTICE	AVG. RESIDUE COVER (%)		AVG. SLOPE (%)		AVG. ANTECEDANT MOISTURE (%)	
PT90	essex test	winter wheat	2x discing	64	a*	2.4	a	18.6	a
	essex control	winter wheat	fall moldboard	5	b	5.3	b	18.6	a
	kettle creek test	corn	notill	80	a	6.5	a	34.1	a
	kettle creek control	corn	fall moldboard	3	b	11.4	b	31	a
	pittock test	corn	fall modified moldboard	10	a	13.2	a	37.3	a
	pittock control	corn	fall moldboard	3	a	7.2	b	32.6	b
PP91	essex test	winter wheat	2x disc	90	a	1.3	a	27.6	a
	essex control	winter wheat	fall moldboard	10	b	4.2	b	15.5	b
	kettle creek test	corn	notill	83	a	6.4	a	28.6	a
	kettle creek control	corn	fall moldboard	10	b	6.8	a	28	a
	pittock test	alfalfa	2x chisel plow	38	a	4.2	a	28.6	a
	pittock control	alfalfa	fall moldboard	12	b	3	a	16	b
PH91	essex test	soybeans	2x discing	54	a	2	a	16.5	a
	essex control	soybeans	fall moldboard	67	b	3.7	a	15.5	a
	kettle creek test	corn	notill	91	a	3.3	a	16	a
	kettle creek control	corn	fall moldboard	83	a	5.5	a	8.8	b
	pittock test	corn	notill	90	a	2.6	a	35	a
	pittock control	corn	fall moldboard	85	a	1.2	a	19.3	b
PT91	essex test	soybeans	2x discing	39	a	1.3	a	15.6	a
	essex control	soybeans	fall moldboard	36	a	2.1	a	14.9	b
	kettle creek test	corn	notill	91	a	3.3	a	16	a
	kettle creek control	corn	fall moldboard	8	b	6.3	b	23.9	b
	pittock test	corn	notill	90	a	2.6	a	35	a
	pittock control	corn	fall moldboard	3	b	8.9	b	34.1	a
PP92	essex test	soybeans	2x discing	50	a	1.6	a	21.8	a
	essex control	soybeans	fall moldboard	5	b	5.1	b	24.5	a
	kettle creek test	corn	notill	93	a	2.7	a	23	a
	kettle creek control	corn	fall moldboard	30	b	3	a	25.5	a
	pittock test	corn	notill	80	a	1.8	a	29.8	a
	pittock control	corn	fall moldboard	16	b	3.2	a	22.7	b

* Test and control pairs with the same letter are not significantly different at alpha = 0.05

TABLE 3.18: SUMMARY OF RAINFALL SIMULATION RESULTS, TOTAL SUSPENDED SOLIDS LOADS

Watershed	Measurement Period		
	Post-Harvest (Fall)	Pre-Plant (Spring)	Post-Tillage (Fall)
Essex	Test > Control due to higher runoff	Control >> Test due to much higher runoff and TSS concentrations	Control > Test due to higher runoff and slightly higher TSS concentrations
Kettle Creek	Control > Test due to higher runoff	Control > Test due to much greater TSS concentrations despite much lower runoff volumes	Control > Test due to much greater TSS concentrations despite much lower runoff volumes
Pittock	Test >> Control due to much higher runoff volumes	Control >> Test due to much higher TSS concentrations	Test >> Control due to much higher runoff volumes

> - greater than
>> - much greater than

TABLE 3.19: SUMMARY OF RAINFALL SIMULATION RESULTS, TOTAL PHOSPHORUS LOADS

Watershed	Measurement Period		
	Post-Harvest (Fall)	Pre-Plant (Spring)	Post-Tillage (Fall)
Essex	Test > Control due to higher runoff and TP concentrations	Control >> Test due to much higher runoff and TP concentrations	Control >> Test due to higher runoff and TP concentrations
Kettle Creek	Control = Test	Control > Test due to much greater TP concentrations despite much lower runoff volumes	Test > Control due to higher runoff volumes and TP concentrations
Pittock	Test > Control due to higher runoff volumes	Control >> Test due to much higher TP concentrations	Test >> Control due to much higher runoff volumes

> - greater than
>> - much greater than

TABLE 3.20: GROUNDWATER TOTAL PHOSPHORUS CONCENTRATION

Site	TP Sample Count	TP Avg.	TP Std.	TP Max.	TP Min.
ECGL1	31	0.031	0.101	0.540	<.001
ECGL2	22	0.038	0.091	0.390	<.001
ETGL1	35	0.062	0.200	1.09	<.001
ETGL2	28	0.144	0.630	3.40	<.001
KCGL1	32	0.013	0.017	0.068	<.002
KCGL2	45	0.007	0.011	0.049	<.002
KTGL1	34	1.31	4.41	19.0	<.001
KTGL2	34	0.042	0.116	0.680	<.001
PCGL1	23	0.367	0.747	3.00	0.006
PCGL2	28	0.249	0.468	2.20	0.001
PTGL1	24	0.268	0.475	2.40	0.003
PTGL2	29	0.506	1.49	7.90	0.004

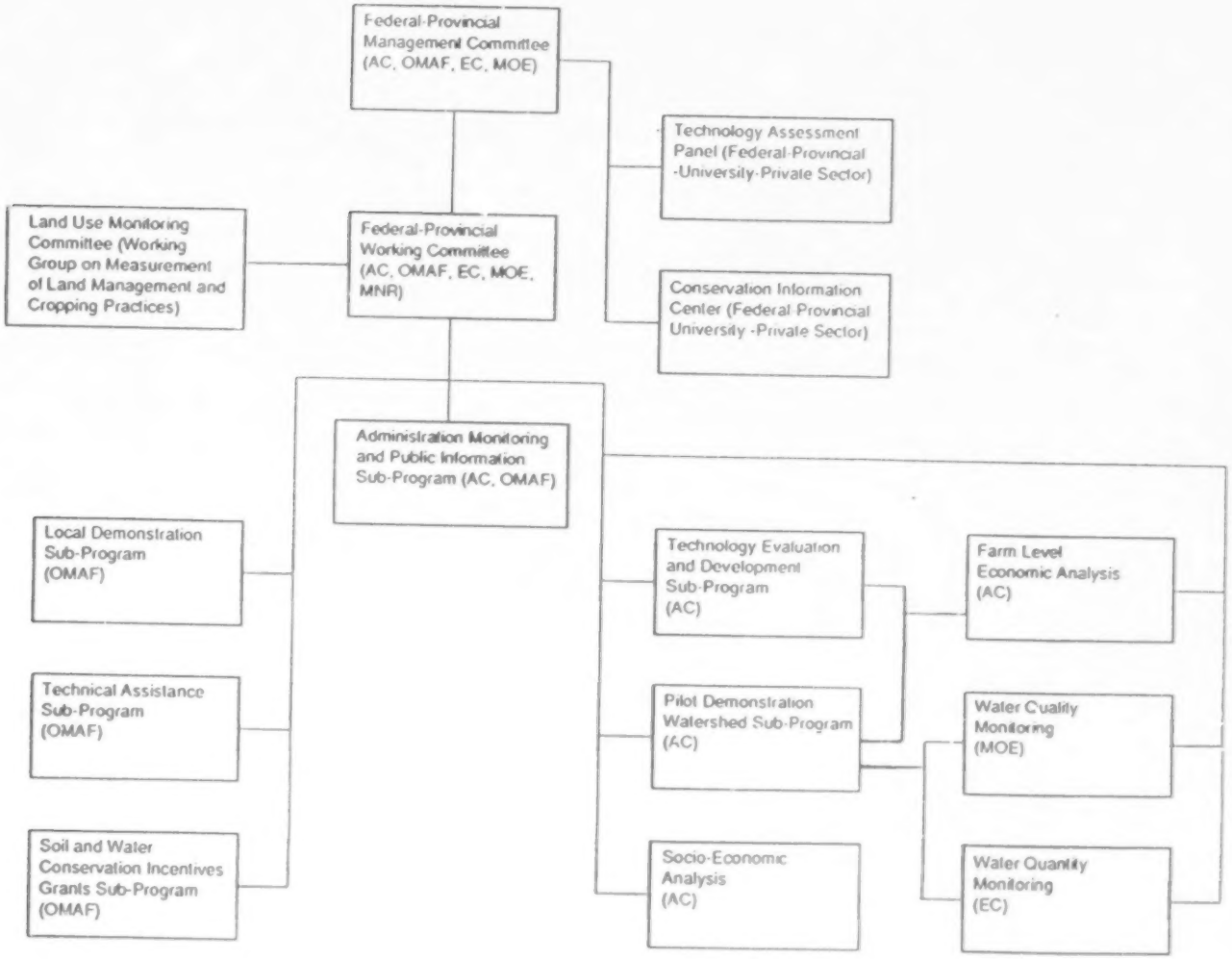
All values are in mg/L.

Table 3.21: Groundwater Total Phosphorous Concentrations (1989-1992)

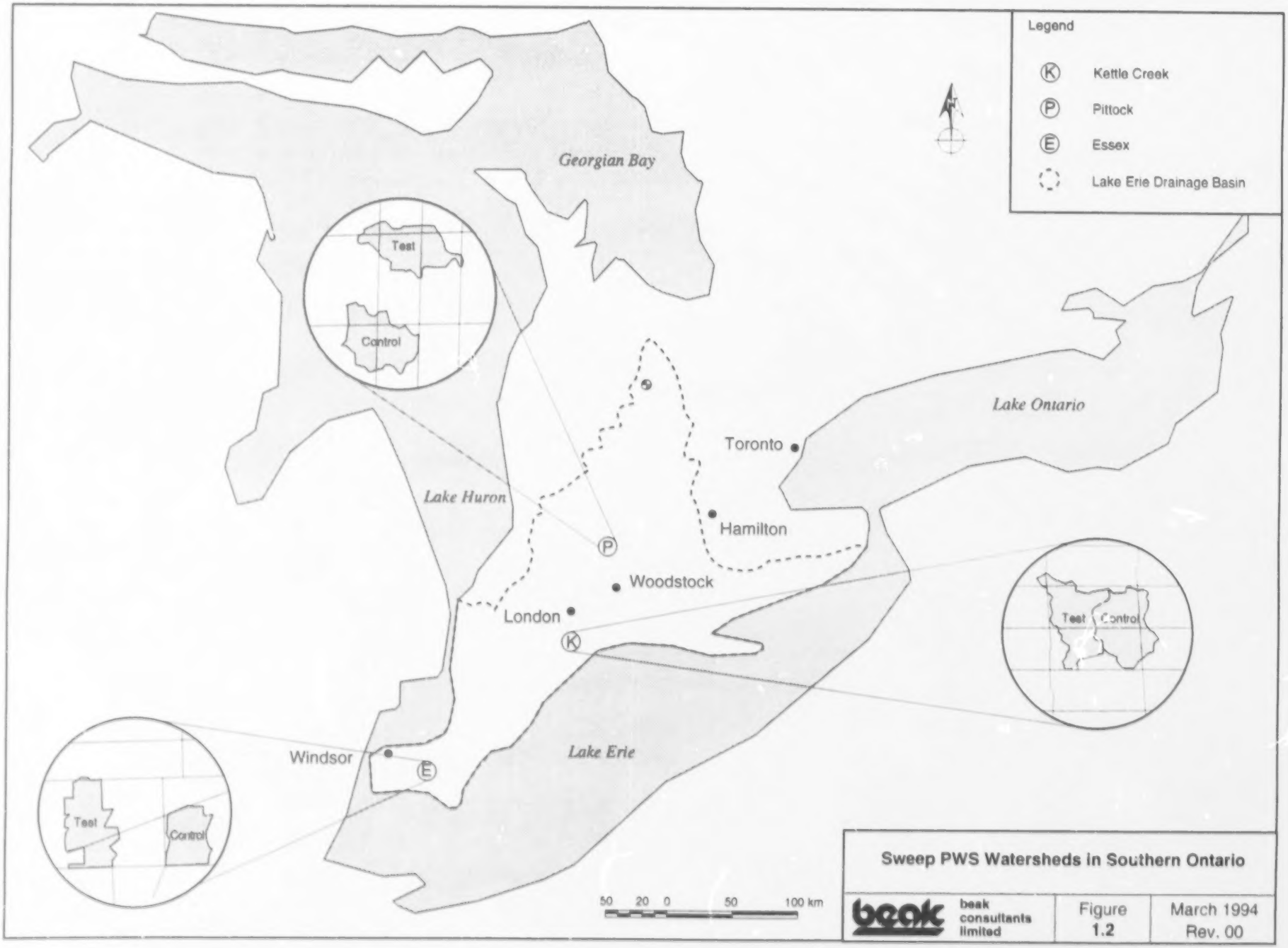
Site	Year	TP Sample Count	TP Avg.	TP STD.	TP Max	TP Min.
ECGL1	1989	9	0.007	0.007	0.026	<.001
ECGL1	1990	10	0.013	0.019	0.065	<.001
ECGL1	1991	7	0.111	0.191	0.540	<.001
ECGL1	1992	5	0.001	0.001	0.002	0.002
ECGL2	1990	8	0.018	0.011	0.034	<.001
ECGL2	1991	6	0.111	0.151	0.390	<.001
ECGL2	1992	5	0.001	0.001	0.002	<.001
ETGL1	1989	9	0.001	0.001	0.002	<.001
ETGL1	1990	11	0.003	0.002	0.007	<.001
ETGL1	1991	8	0.219	0.382	1.09	0.003
ETGL1	1992	5	0.002	0.002	0.004	0.002
ETGL2	1989	6	0.005	0.002	0.010	0.003
ETGL2	1990	9	0.008	0.005	0.016	<.001
ETGL2	1991	7	0.510	1.18	3.40	<.001
ETGL2	1992	5	0.001	0.001	0.003	<.001
KCGL1	1990	16	0.019	0.016	0.052	0.001
KCGL1	1991	11	0.010	0.019	0.068	<.001
KCGL1	1992	5	0.001	0.001	0.002	<.001
KCGL2	1989	5	0.009	0.002	0.011	0.005
KCGL2	1990	20	0.008	0.010	0.048	0.001
KCGL2	1991	12	0.007	0.013	0.049	<.001
KCGL2	1992	6	0.002	0.001	0.004	0.002
KTGL1	1990	13	0.020	0.018	0.060	<.001
KTGL1	1991	9	0.016	0.018	0.064	0.004
KTGL1	1992	5	0.025	0.021	0.061	0.002
KTGL2	1990	17	0.027	0.029	0.085	<.001
KTGL2	1991	9	0.074	0.202	0.680	<.001
KTGL2	1992	4	0.001	0.002	0.005	<.001
PCGL1	1990	9	0.038	0.023	0.077	0.008
PCGL1	1991	8	0.315	0.611	1.91	0.006
PCGL1	1992	1	0.058	0.000	0.058	0.058
PCGL2	1990	10	0.027	0.022	0.065	0.003
PCGL2	1991	11	0.171	0.172	0.460	0.001
PCGL2	1992	1	0.006	0.000	0.006	0.006
PTGL1	1990	6	0.021	0.015	0.043	<0.001
PTGL1	1991	9	0.268	0.206	0.590	0.003
PTGL1	1992	1	0.004	0.000	0.004	0.004
PTGL2	1990	9	0.036	0.027	0.088	0.004
PTGL2	1991	12	0.123	0.107	0.330	0.004
PTGL2	1992	1	0.049	0.000	0.049	0.049

All values are in mg/L

Figure 1.1: SWEEP Organizational Structure


Federal-Provincial Management Committee (AC, OMAF, EC, MOE)
Technology Assessment Panel (Federal-Provincial -University-Private Sector)
Land Use Monitoring Committee (Working Group on Measurement of Land Management and Cropping Practices)
Federal-Provincial Working Committee (AC, OMAF, EC, MOE, MNR)
Conservation Information Center (Federal-Provincial University -Private Sector)
Administration Monitoring and Public Information Sub-Program (AC, OMAF)
Local Demonstration Sub-Program (OMAF)
Technology Evaluation and Development Sub-Program (AC)
Farm Level Economic Analysis (AC)
Technical Assistance Sub-Program (OMAF)
Pilot Demonstration Watershed Sub-Program (AC)
Water Quality Monitoring (MOE)
Soil and Water Conservation Incentives Grants Sub-Program (OMAF)
Socio-Economic Analysis (AC)
Water Quantity Monitoring (EC)

Abbreviations
AC Agriculture Canada
EC Environment Canada
MNR Ontario Ministry of Natural Resources
MOE Ontario Ministry of the Environment
OMAF Ontario Ministry of Agriculture and Food

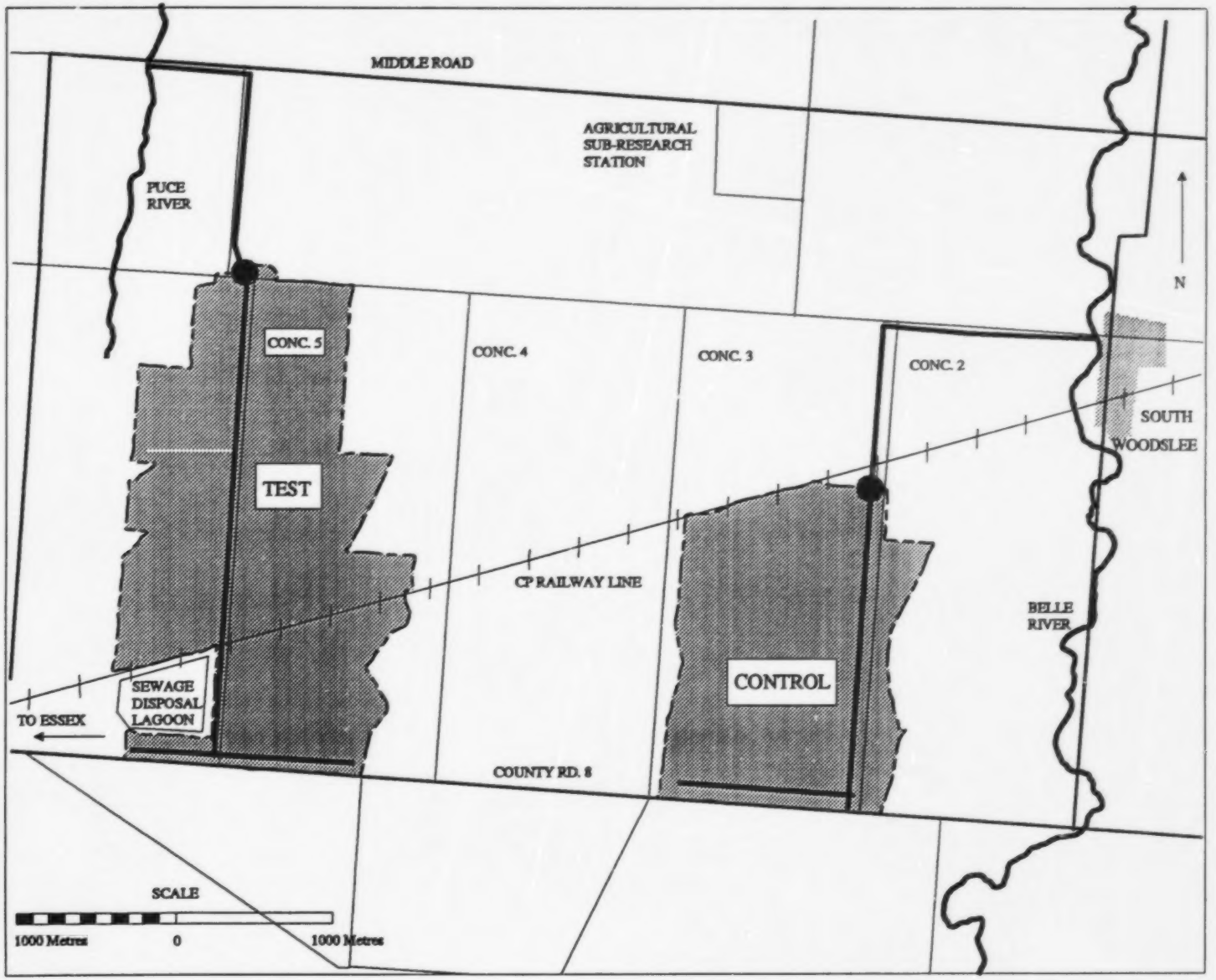


Sweep PWS Watersheds in Southern Ontario

beak consultants limited	Figure 1.2	March 1994 Rev. 00

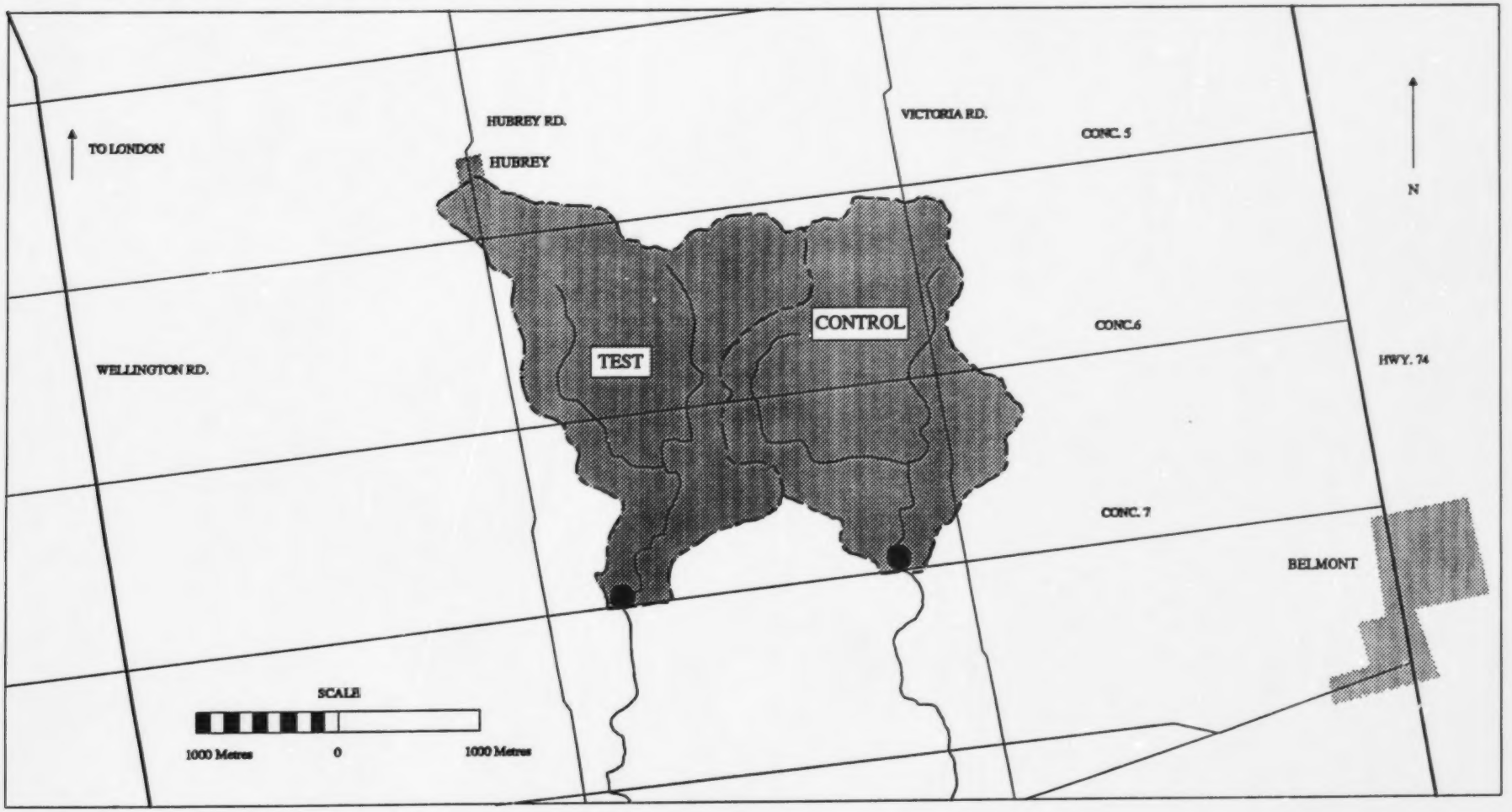
Figure 2.1

ESSEX SUB-WATERSHEDS



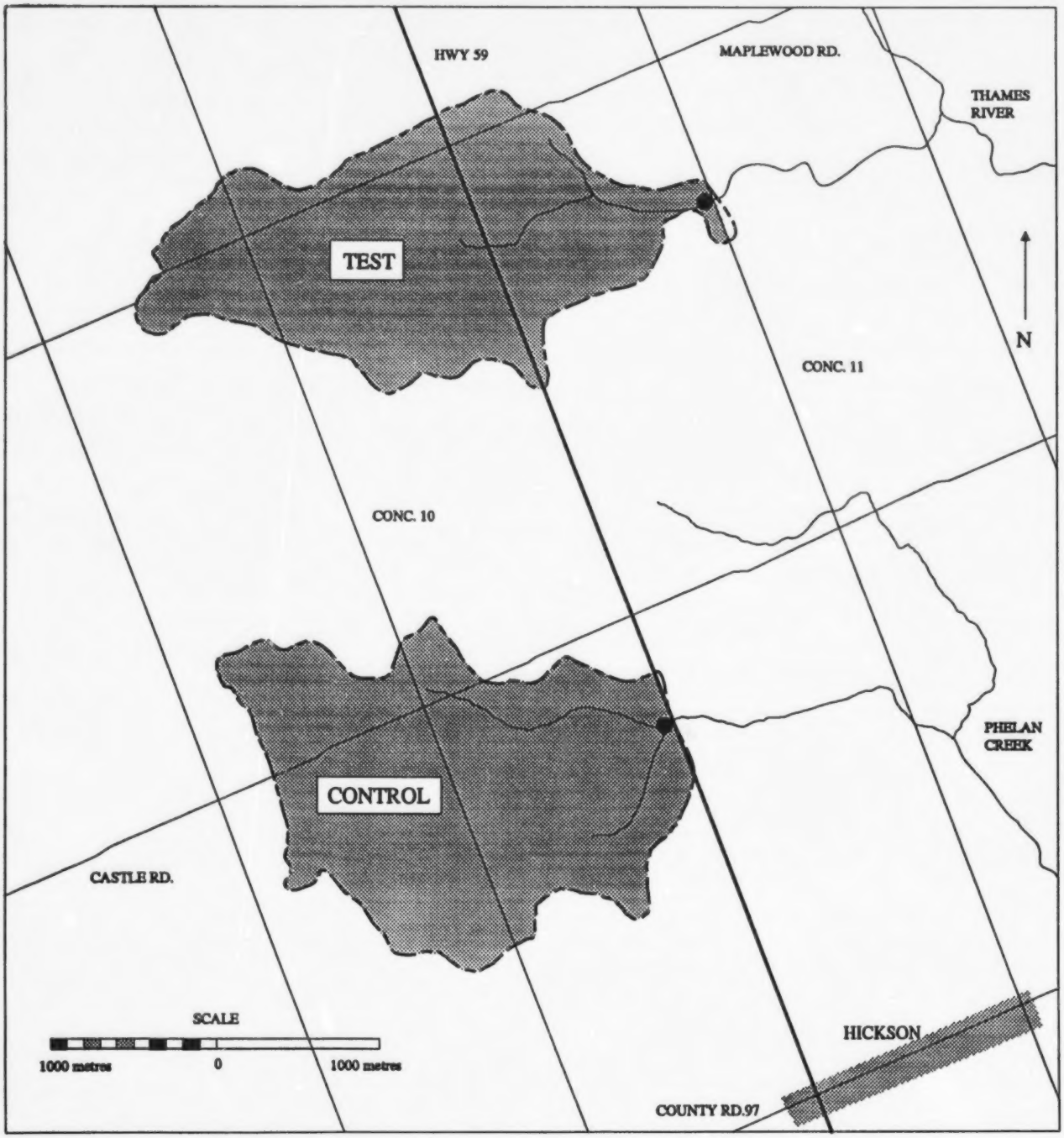
● - sub-watershed mouth monitoring station

Figure 2.2: KETTLE CREEK SUB-WATERSHEDS



-sub-watershed mouth monitoring station

Figure 2.3: PITTOCK SUB-WATERSHEDS



● - sub-watershed mouth monitoring station

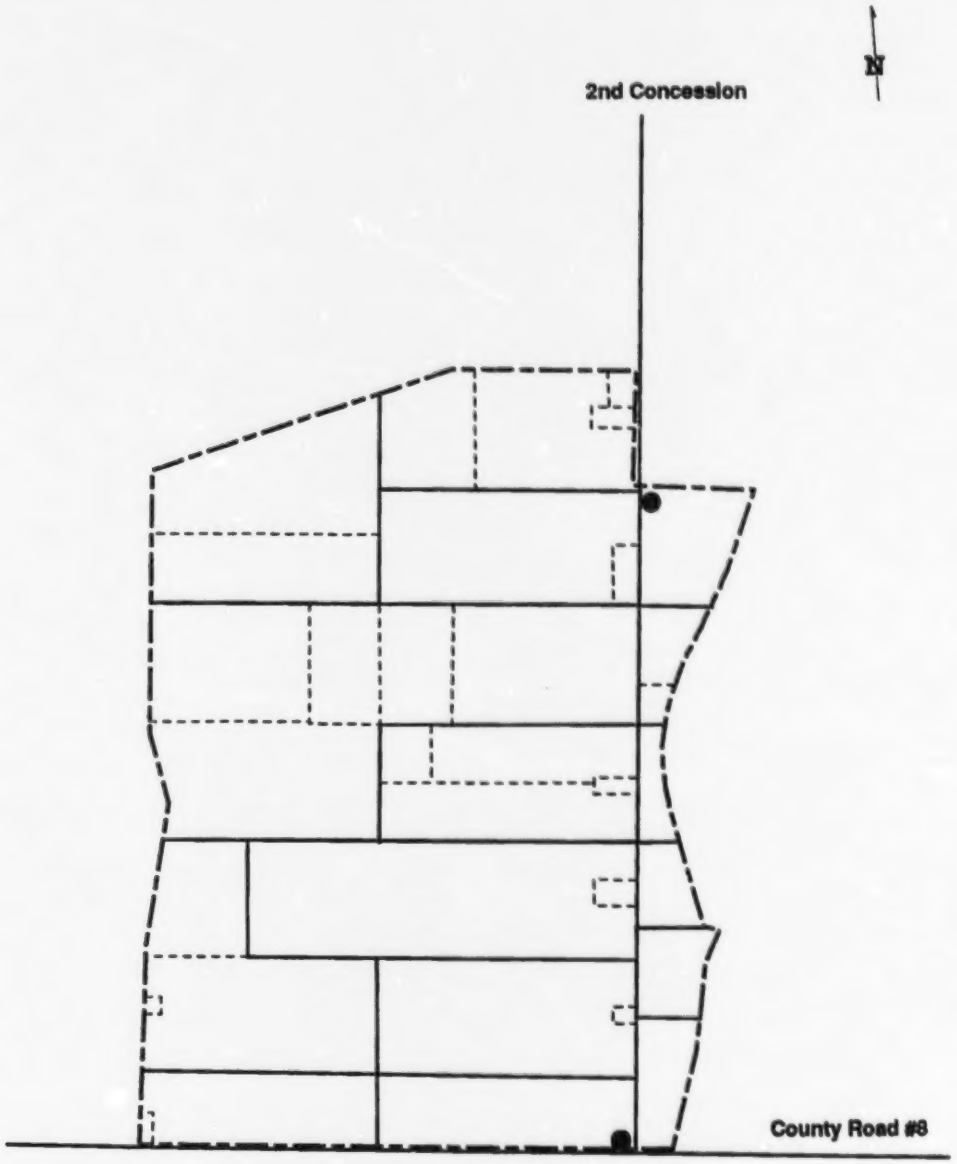


FIGURE 2.4 ESSEX CONTROL SUB-WATERSHED

Piezometer/Soil Moisture Monitoring Locations

● Soil Moisture and Groundwater Monitoring Site

Scale 1:16 000

100m 0 100m 500m 1 km

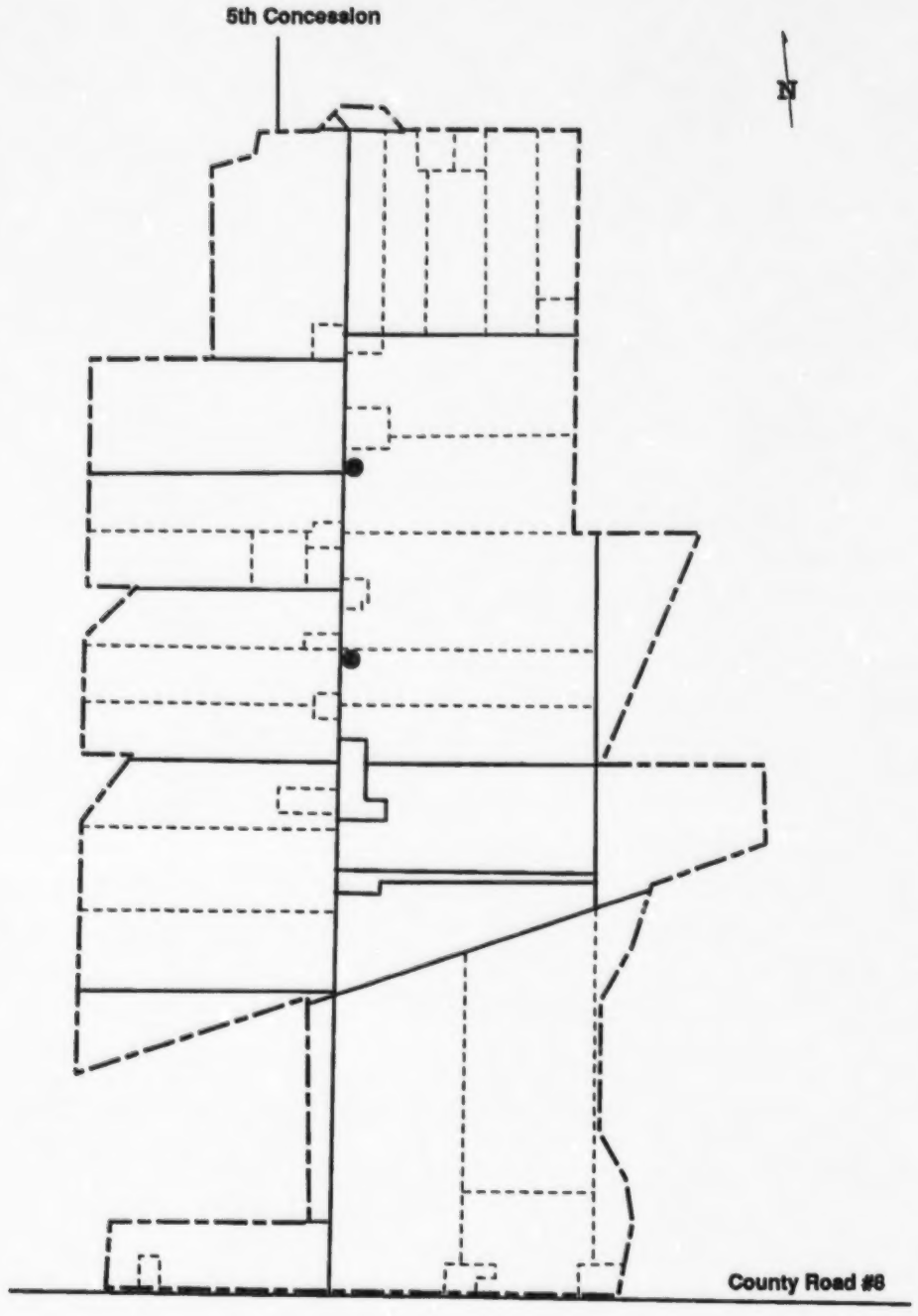


FIGURE 2.5 ESSEX TEST SUB-WATERSHED
Piezometer/Soil Moisture Monitoring Locations

● Soil Moisture and Groundwater Monitoring Site

Scale 1:16 000

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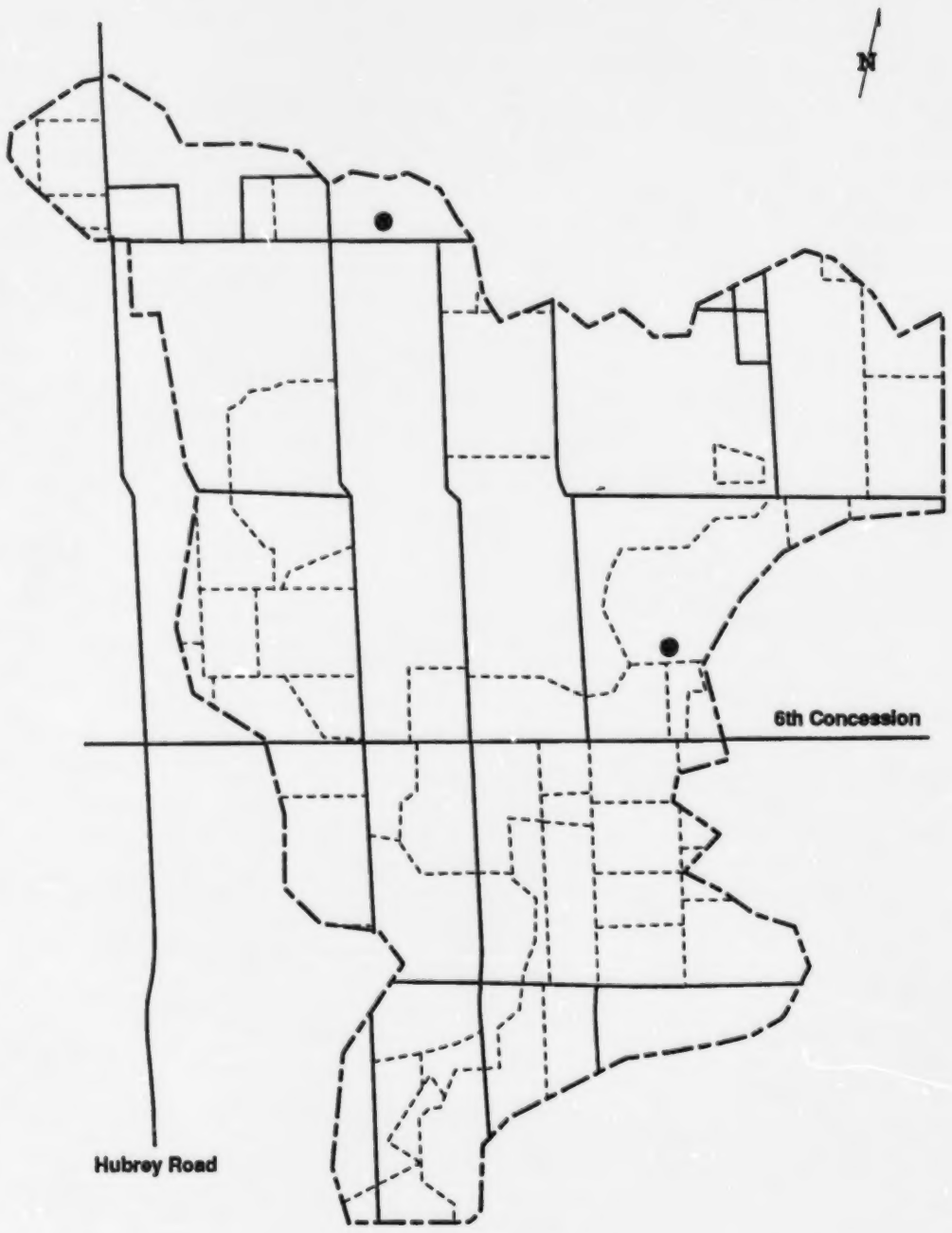

FIGURE 2.6 KETTLE TEST SUB-WATERSHED

Piezometer/Soil Moisture Monitoring Locations

● Soil Moisture and Groundwater Monitoring Site

Scale 1:16 000

100m 0 100m 500m 1 km

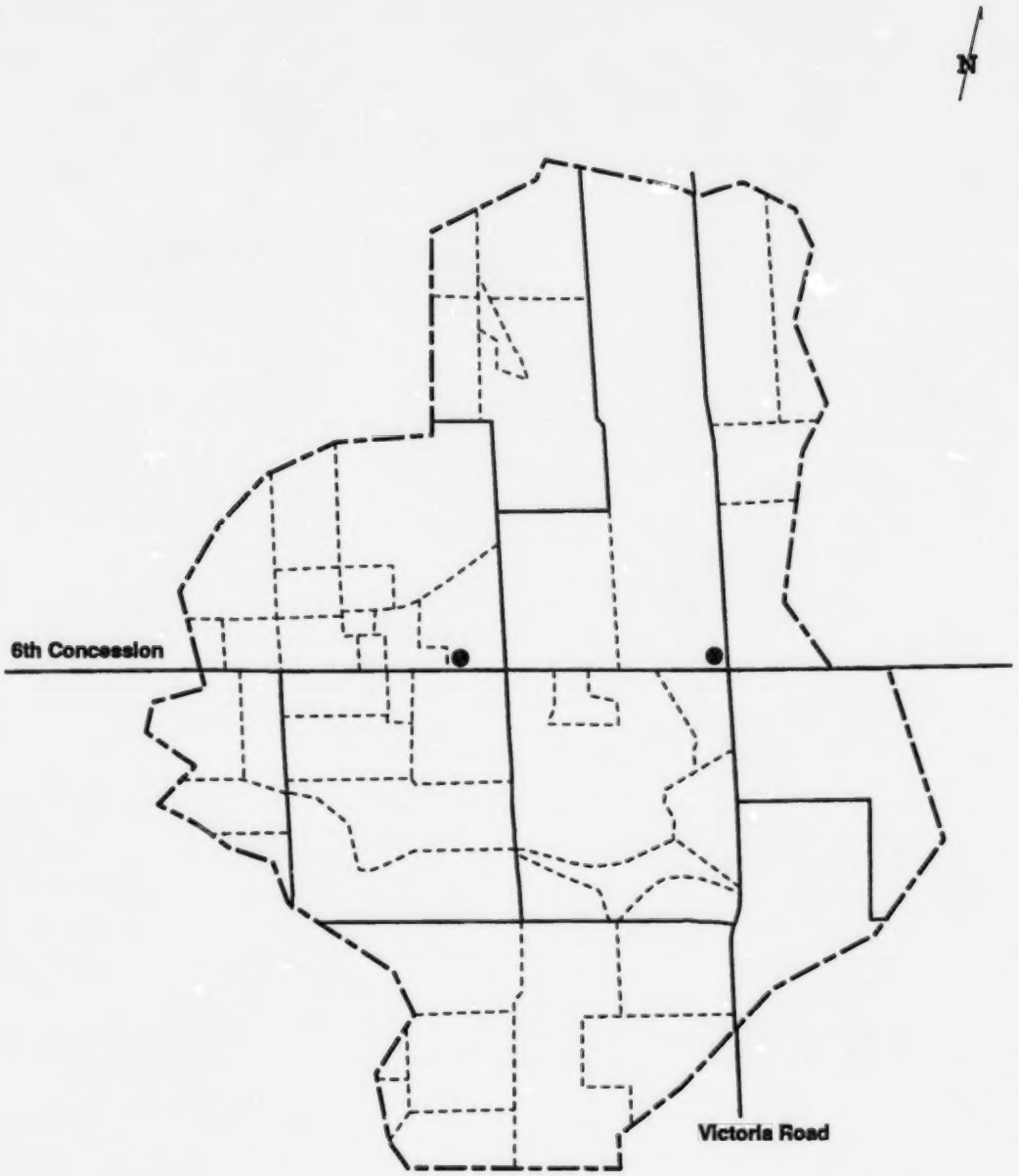

FIGURE 2.7 KETTLE CONTROL SUB-WATERSHED

Piezometer/Soil Moisture Monitoring Locations

● Soil Moisture and Groundwater Monitoring Site

Scale 1:16 000

100m 0 100m 500m 1 km

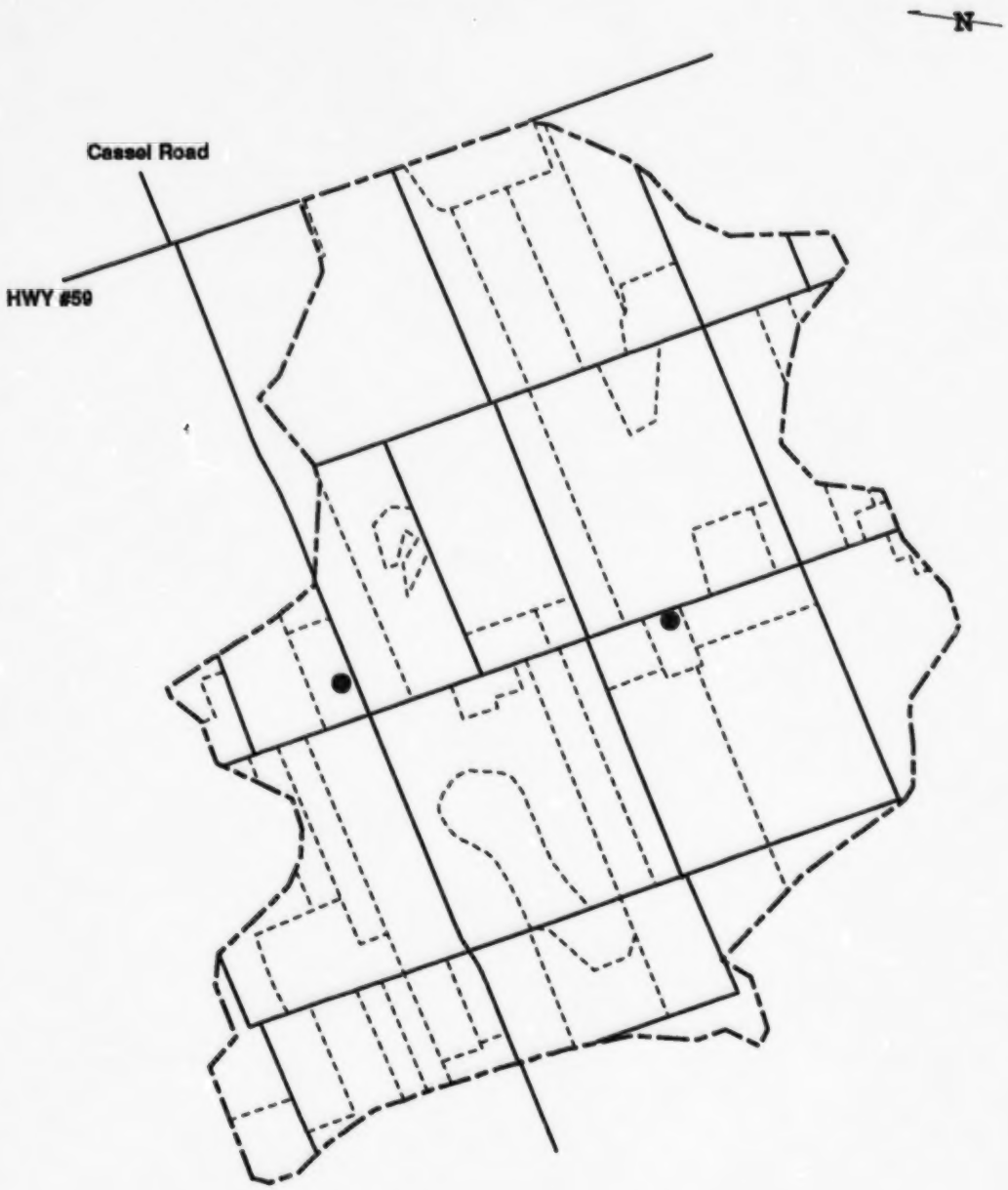

FIGURE 2.8 PITTOCK CONTROL SUB-WATERSHED

Piezometer/Soil Moisture Monitoring Locations

● Soil Moisture and Groundwater Monitoring Site

Scale 1:16 000

100m 0 100m 500m 1km

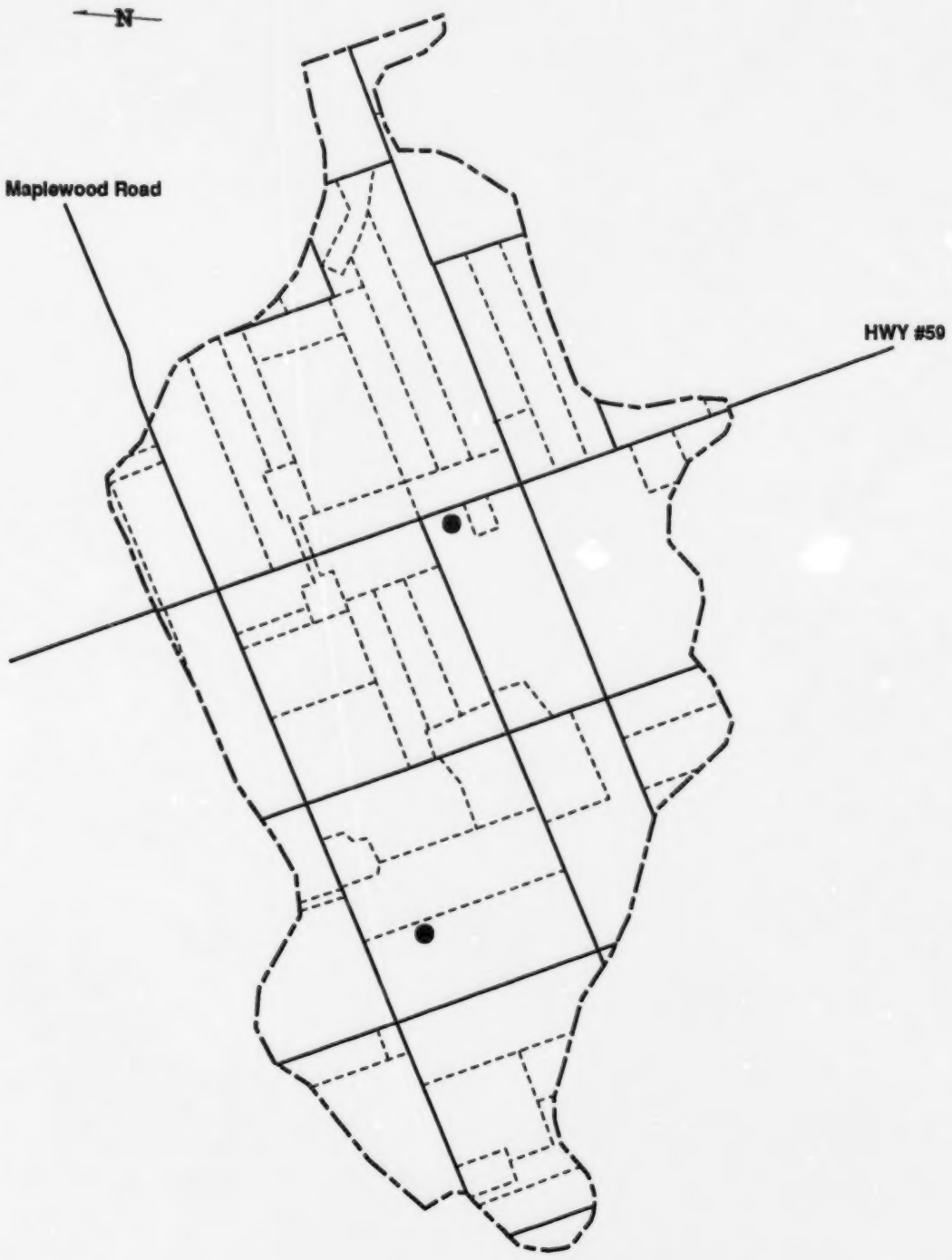

FIGURE 2.9 PITTOCK TEST SUB-WATERSHED

Piezometer/Soil Moisture Monitoring Locations

● Soil Moisture and Groundwater Monitoring Site

Scale 1:16 000

100m 0 100m 500m 1 km

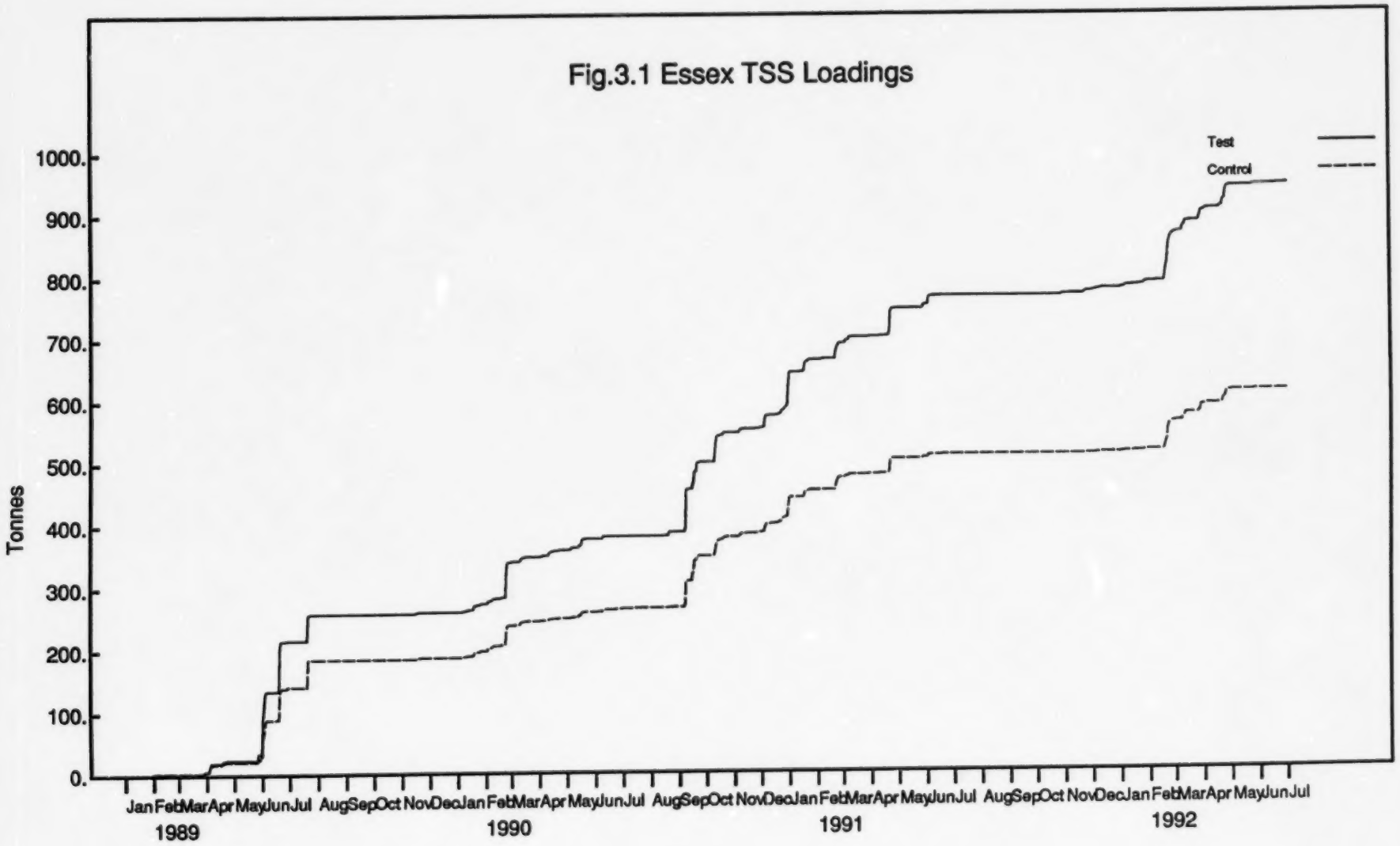
Fig.3.1 Essex TSS Loadings
Test
Control
Tonnes
1000.
900.
800.
700.
600.
500.
400.
300.
200.
100.
0.
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec Jan Feb Mar Apr May Jun Jul
1989
1990
1991
1992

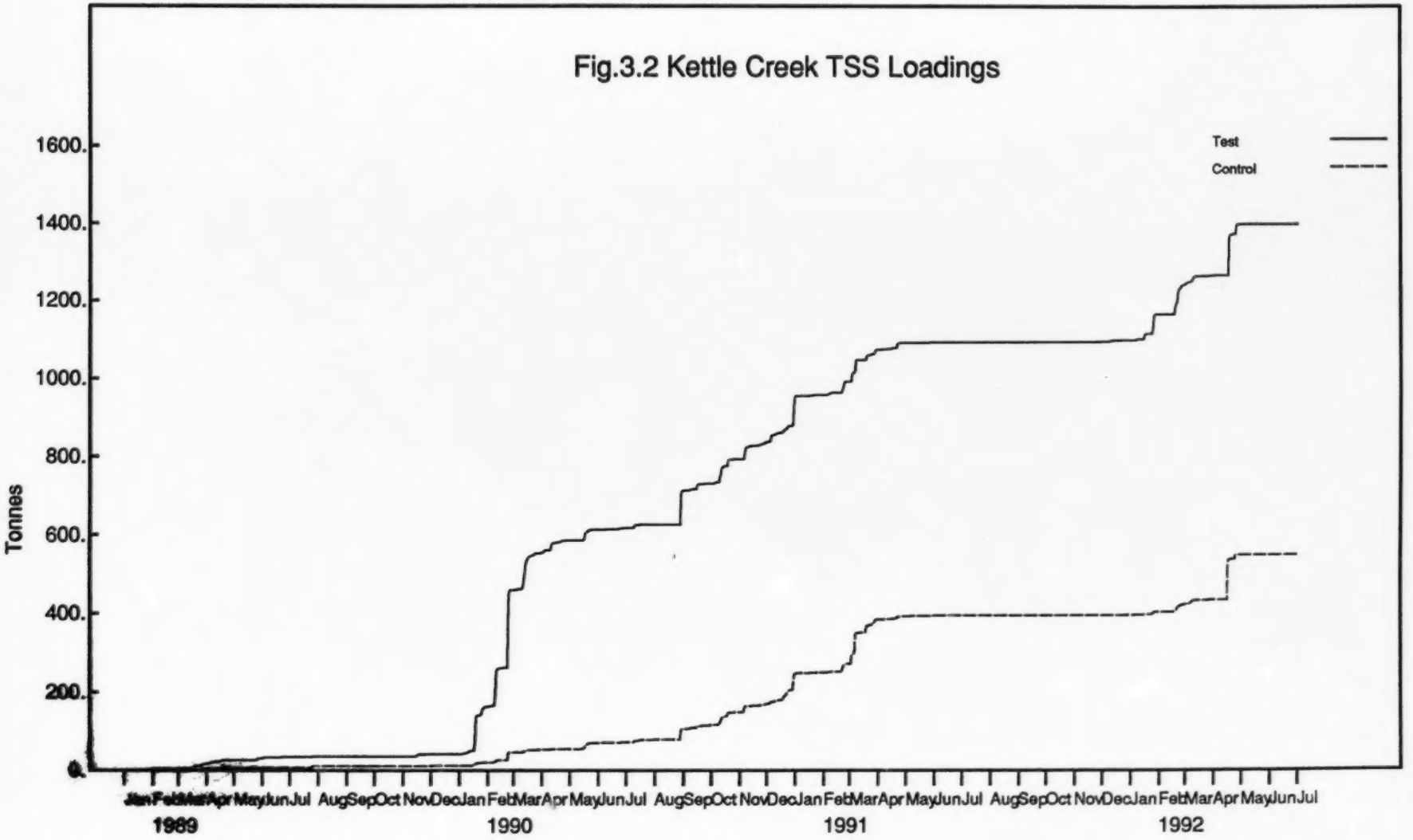
Fig.3.2 Kettle Creek TSS Loadings
Test
Control
Tonnes
1600.
1400.
1200.
1000.
800.
600.
400.
200.
0.
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec Jan Feb Mar Apr May Jun Jul
1989
1990
1991
1992

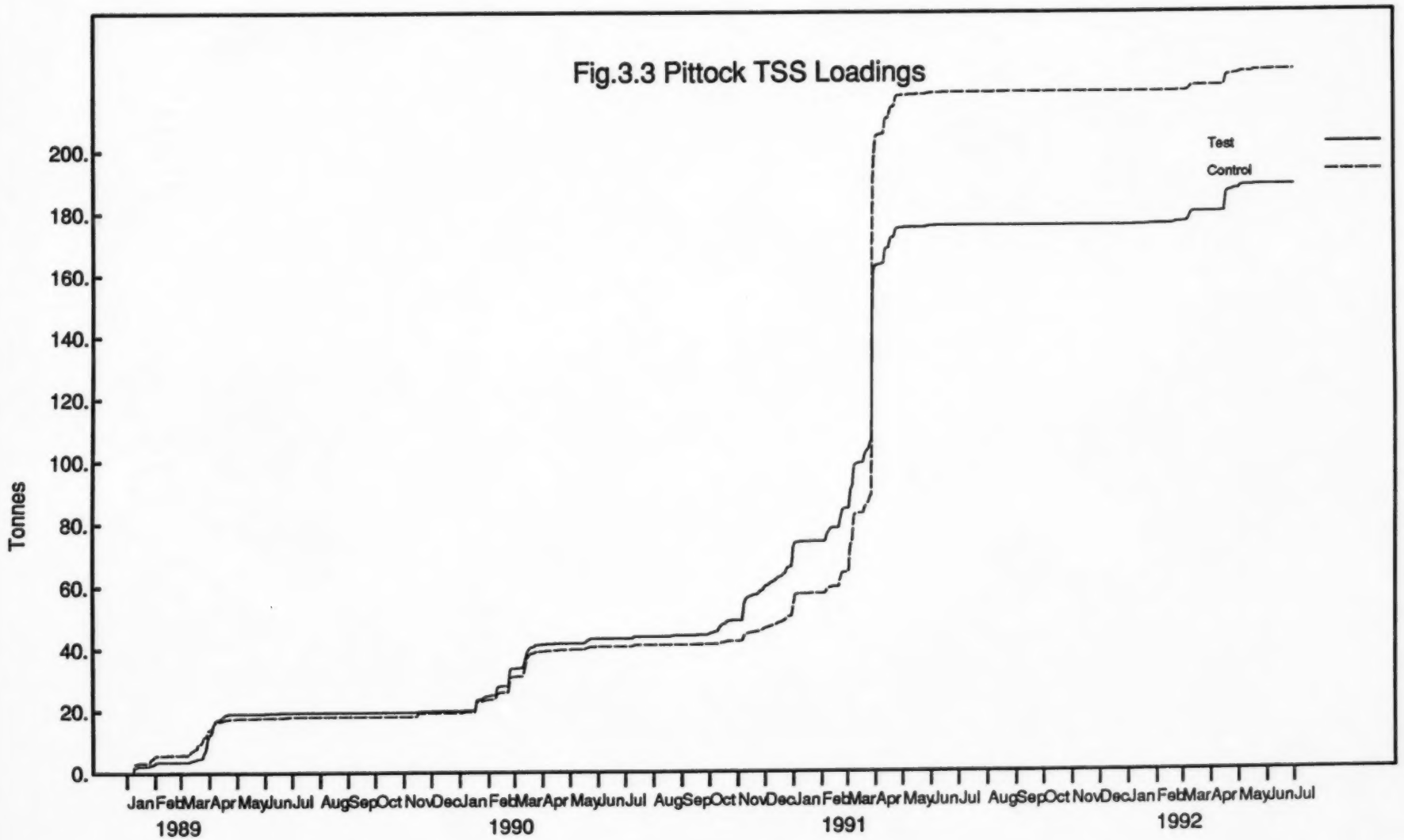
Fig.3.3 Pittock TSS Loadings
Test
Control
Tonnes
200.
180.
160.
140.
120.
100.
80.
60.
40.
20.
0.
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec Jan Feb Mar Apr May Jun Jul
1989
1990
1991
1992

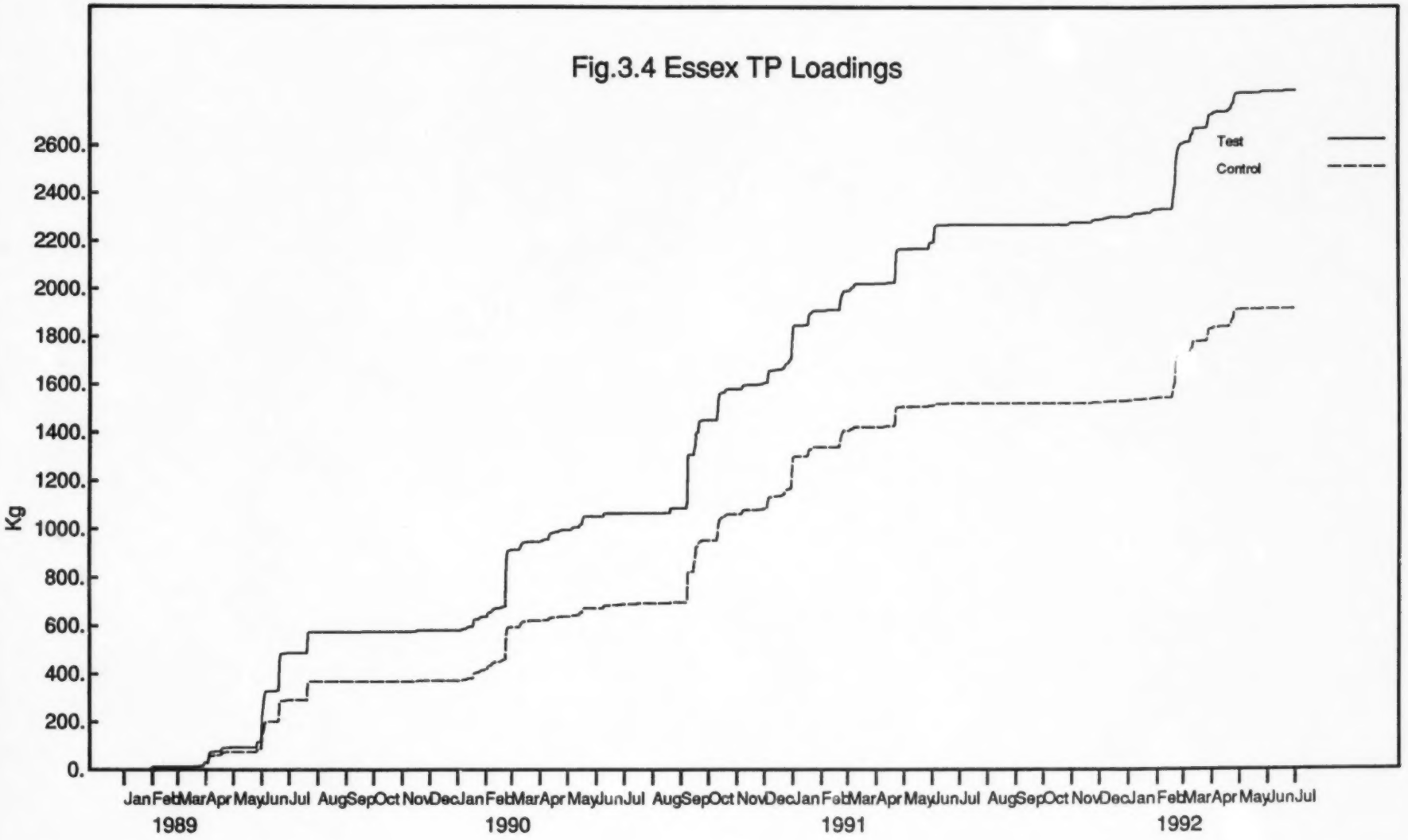
Fig.3.4 Essex TP Loadings
Test
Control
Kg
2600.
2400.
2200.
2000.
1800.
1600.
1400.
1200.
1000.
800.
600.
400.
200.
0.
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec Jan Feb Mar Apr May Jun Jul
1989
1990
1991
1992

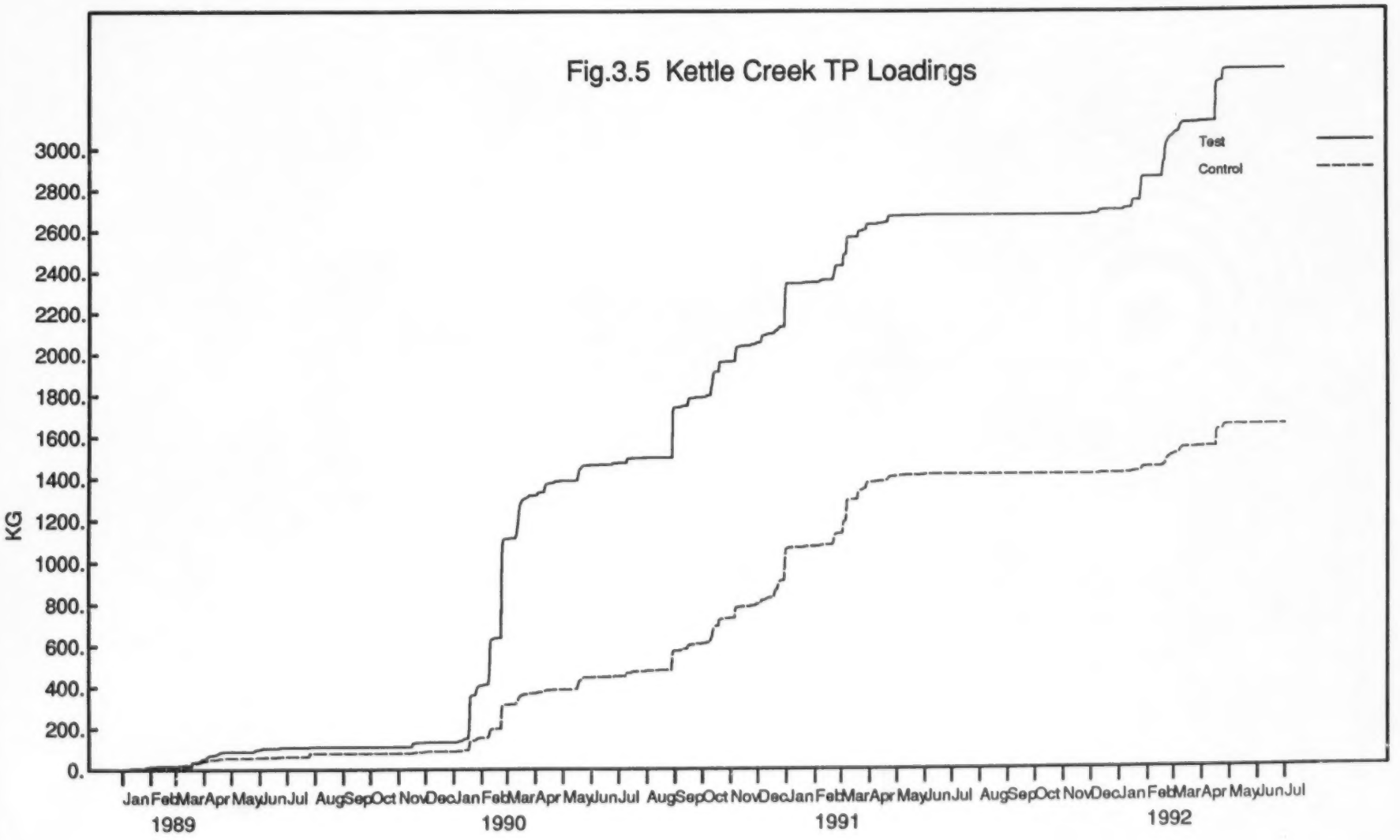
Fig.3.5 Kettle Creek TP Loadings
KG
3000.
2800.
2600.
2400.
2200.
2000.
1800.
1600.
1400.
1200.
1000.
800.
600.
400.
200.
0.
Test
Control
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec Jan Feb Mar Apr May Jun Jul
1989
1990
1991
1992

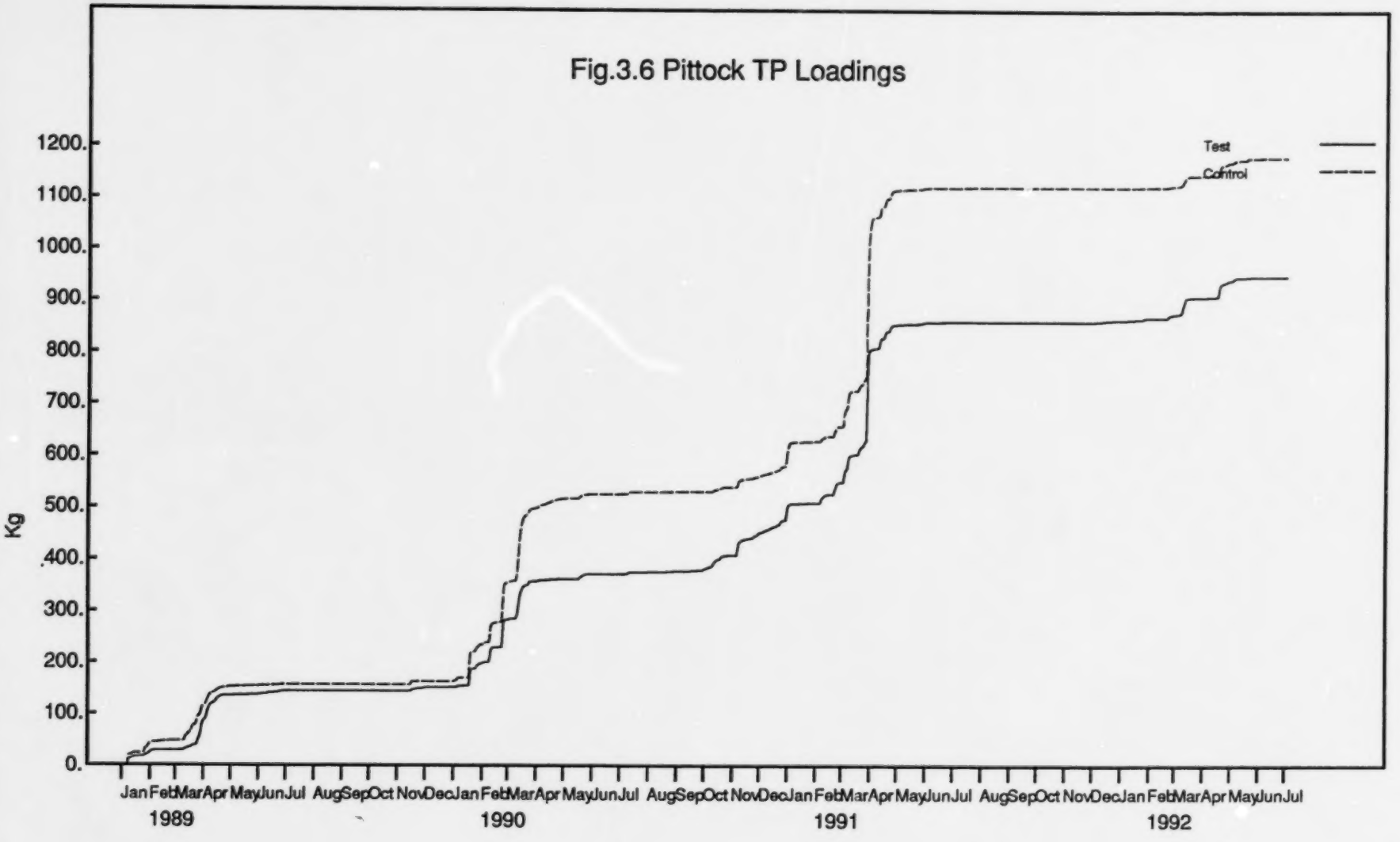
Fig.3.6 Pittock TP Loadings
Test
Control
Kg
1200.
1100.
1000.
900.
800.
700.
600.
500.
400.
300.
200.
100.
0.
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec Jan Feb Mar Apr May Jun Jul
1989
1990
1991
1992

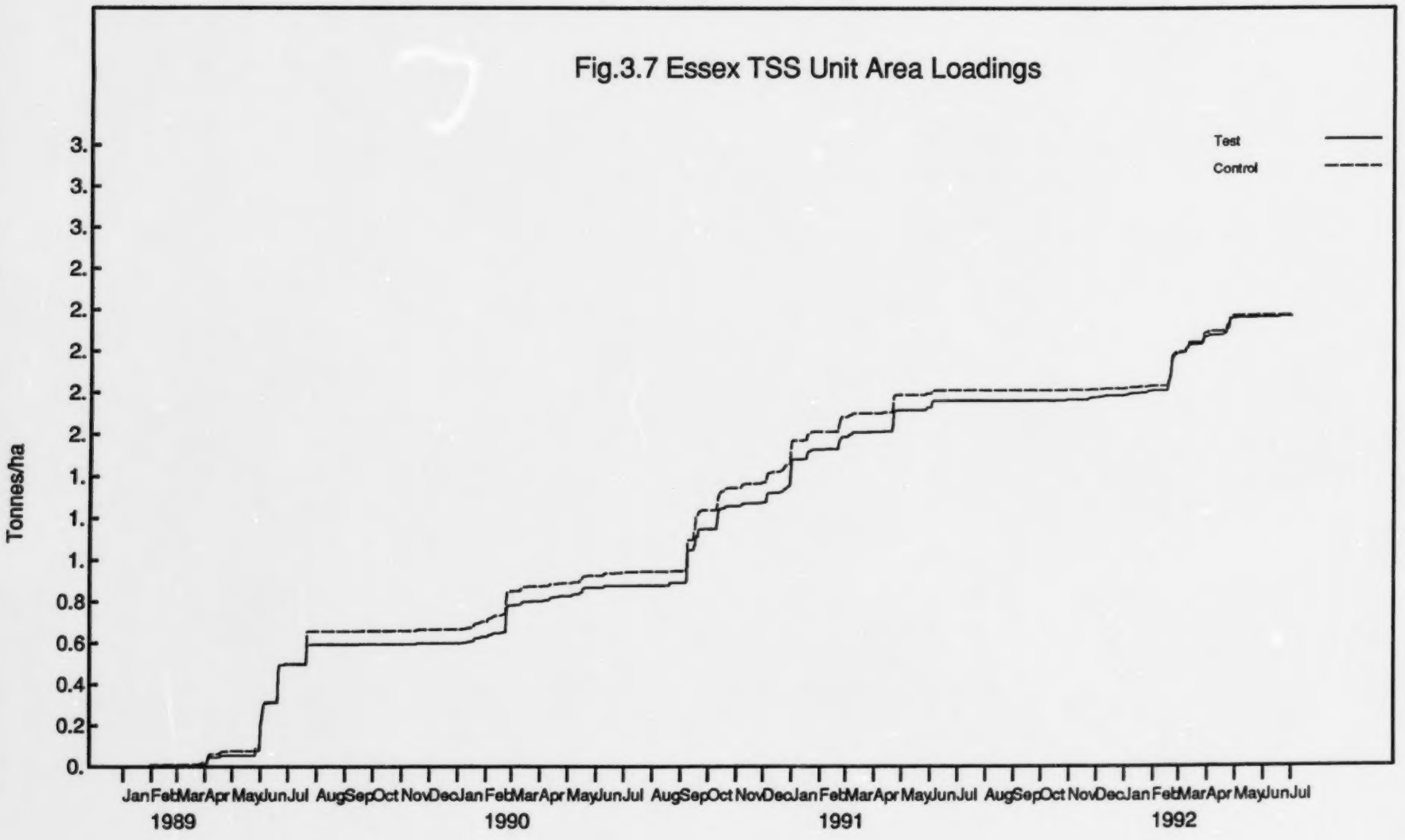
Fig.3.7 Essex TSS Unit Area Loadings
Test
Control
Tonnes/ha
3.
3.
3.
2.
2.
2.
2.
2.
1.
1.
1.
0.8
0.6
0.4
0.2
0.
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec Jan Feb Mar Apr May Jun Jul
1989
1990
1991
1992

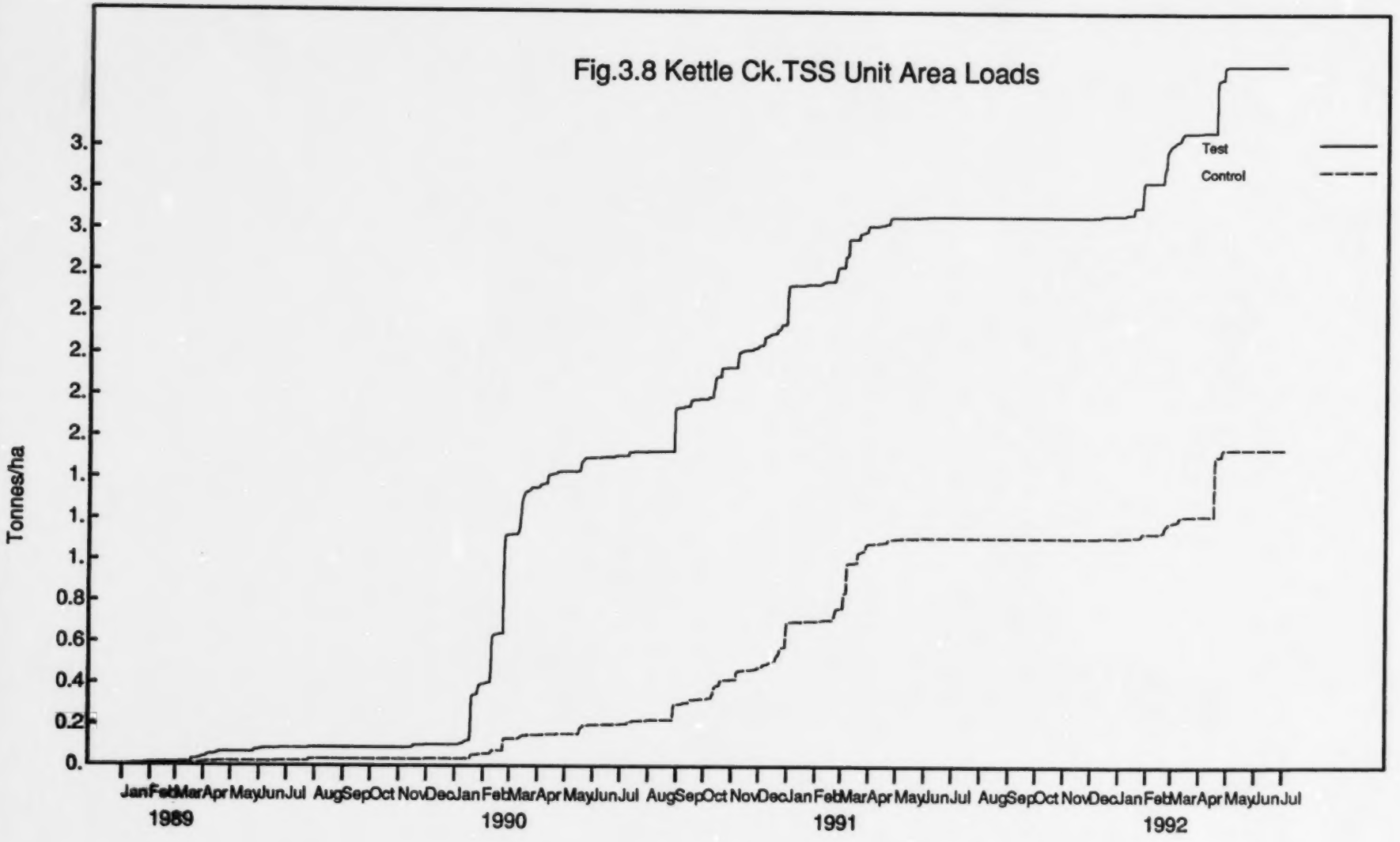
Fig.3.8 Kettle Ck.TSS Unit Area Loads
Tonnes/ha
3.
3.
3.
2.
2.
2.
2.
2.
1.
1.
1.
0.8
0.6
0.4
0.2
0.
Test
Control
JanFebMarAprMayJunJul AugSepOctNovDecJanFebMarAprMayJunJul AugSepOctNovDecJanFebMarAprMayJunJul AugSepOctNovDecJanFebMarAprMayJunJul
1989
1990
1991
1992

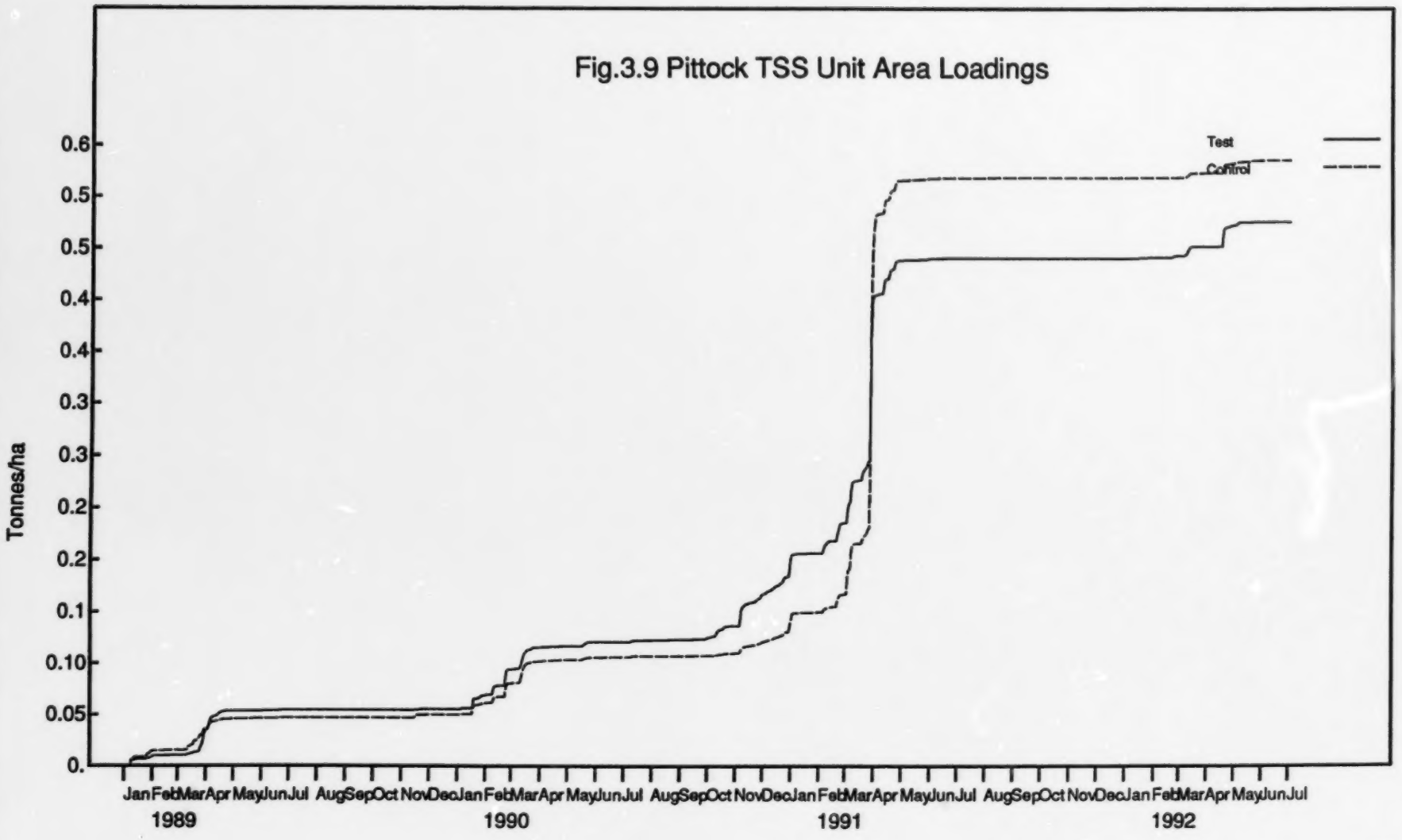
Fig.3.9 Pittock TSS Unit Area Loadings
Test
Control
Tonnes/ha
0.6
0.5
0.5
0.4
0.4
0.3
0.3
0.2
0.2
0.1
0.10
0.05
0.
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec Jan Feb Mar Apr May Jun Jul
1989
1990
1991
1992

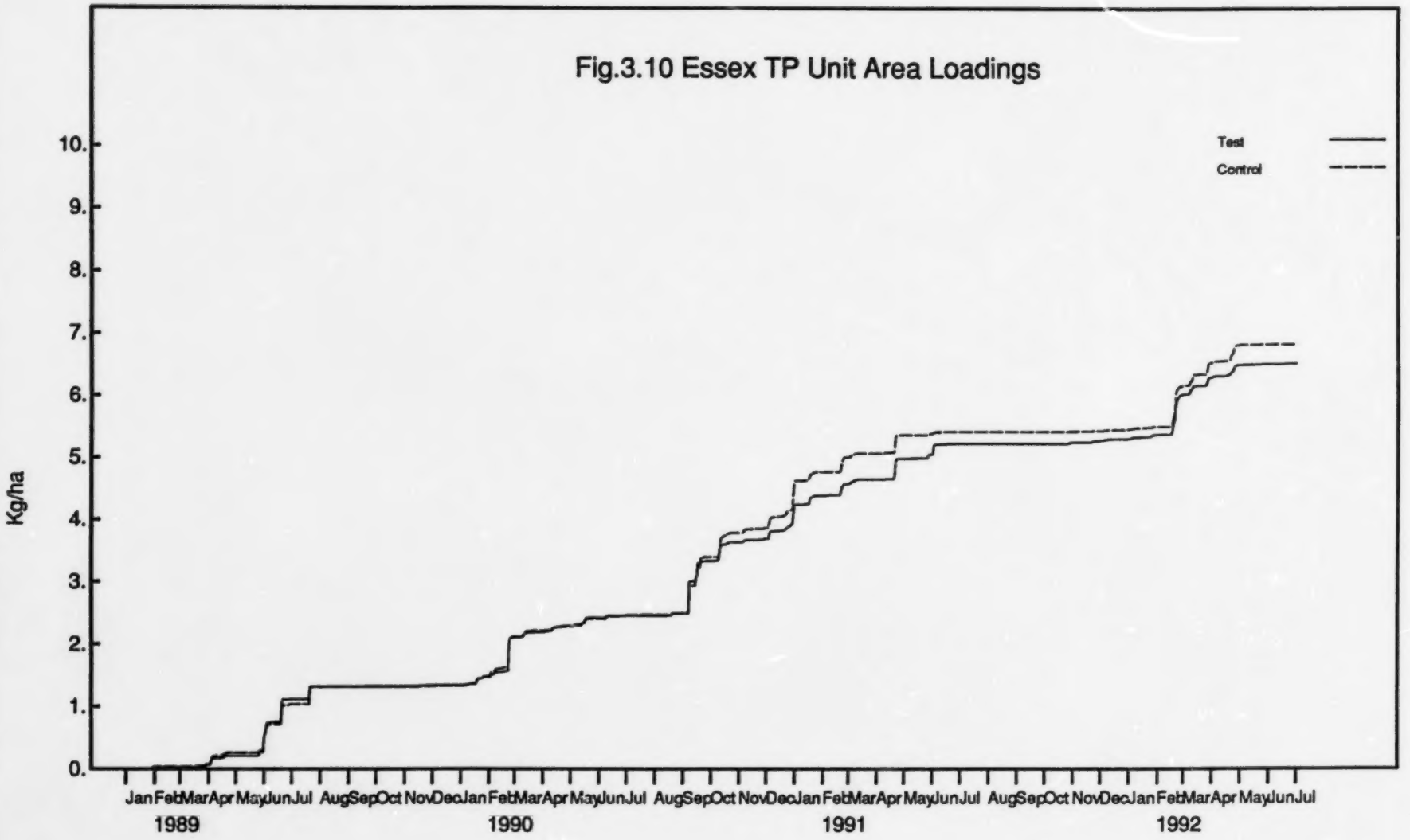
Fig.3.10 Essex TP Unit Area Loadings
Test
Control
Kg/ha
10.
9.
8.
7.
6.
5.
4.
3.
2.
1.
0.
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec Jan Feb Mar Apr May Jun Jul
1989
1990
1991
1992

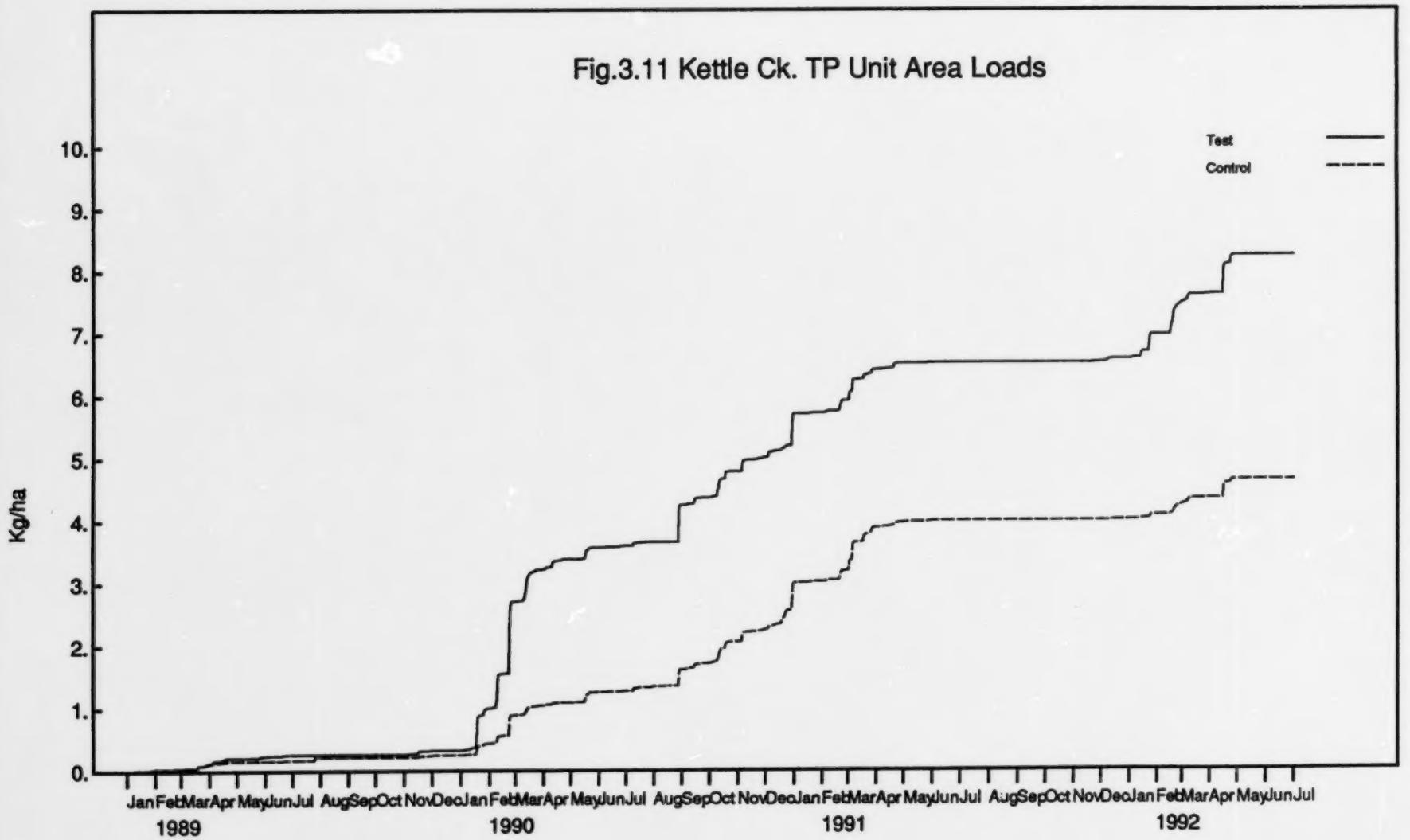
Fig.3.11 Kettle Ck. TP Unit Area Loads
Test
Control
Kg/ha
10.
9.
8.
7.
6.
5.
4.
3.
2.
1.
0.
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec Jan Feb Mar Apr May Jun Jul
1989
1990
1991
1992

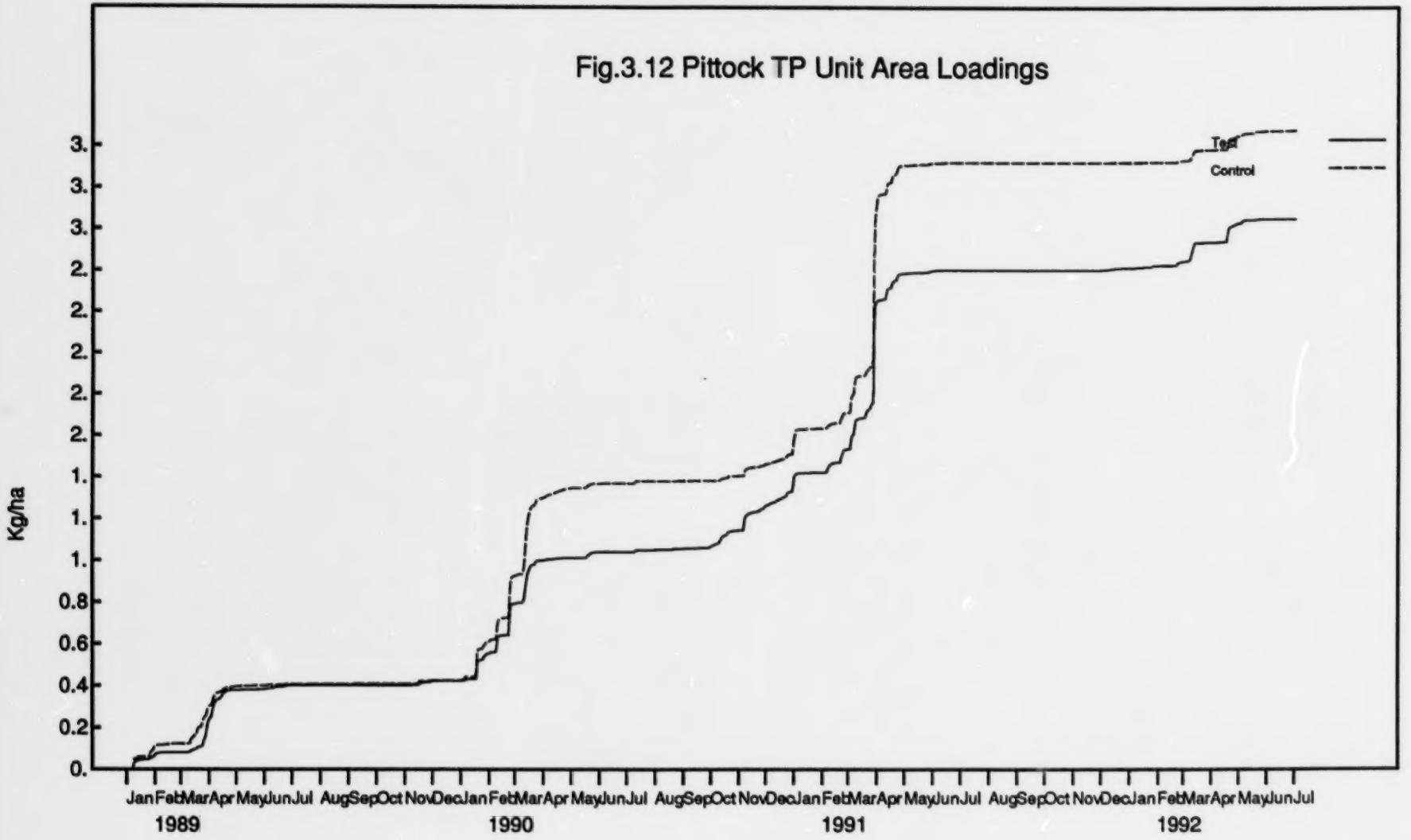
Fig.3.12 Pittock TP Unit Area Loadings
Test
Control
Kg/ha
3.
3.
3.
2.
2.
2.
2.
2.
1.
1.
1.
0.8
0.6
0.4
0.2
0.
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec Jan Feb Mar Apr May Jun Jul
1989
1990
1991
1992

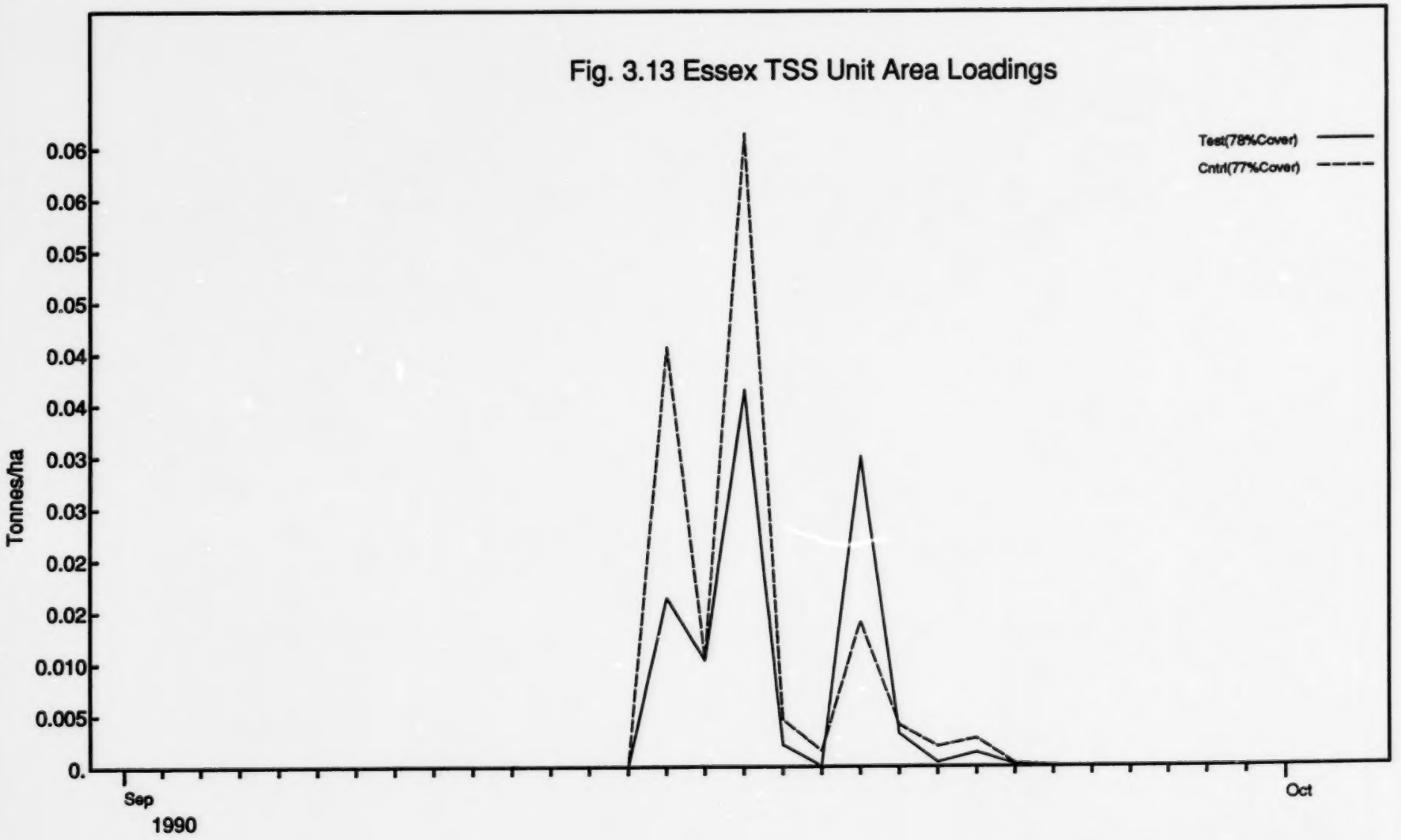
Fig. 3.13 Essex TSS Unit Area Loadings
Test(78%Cover)
Cntrl(77%Cover)
Tonnes/ha
0.06
0.06
0.05
0.05
0.04
0.04
0.03
0.03
0.02
0.02
0.010
0.005
0.
Sep
1990
Oct

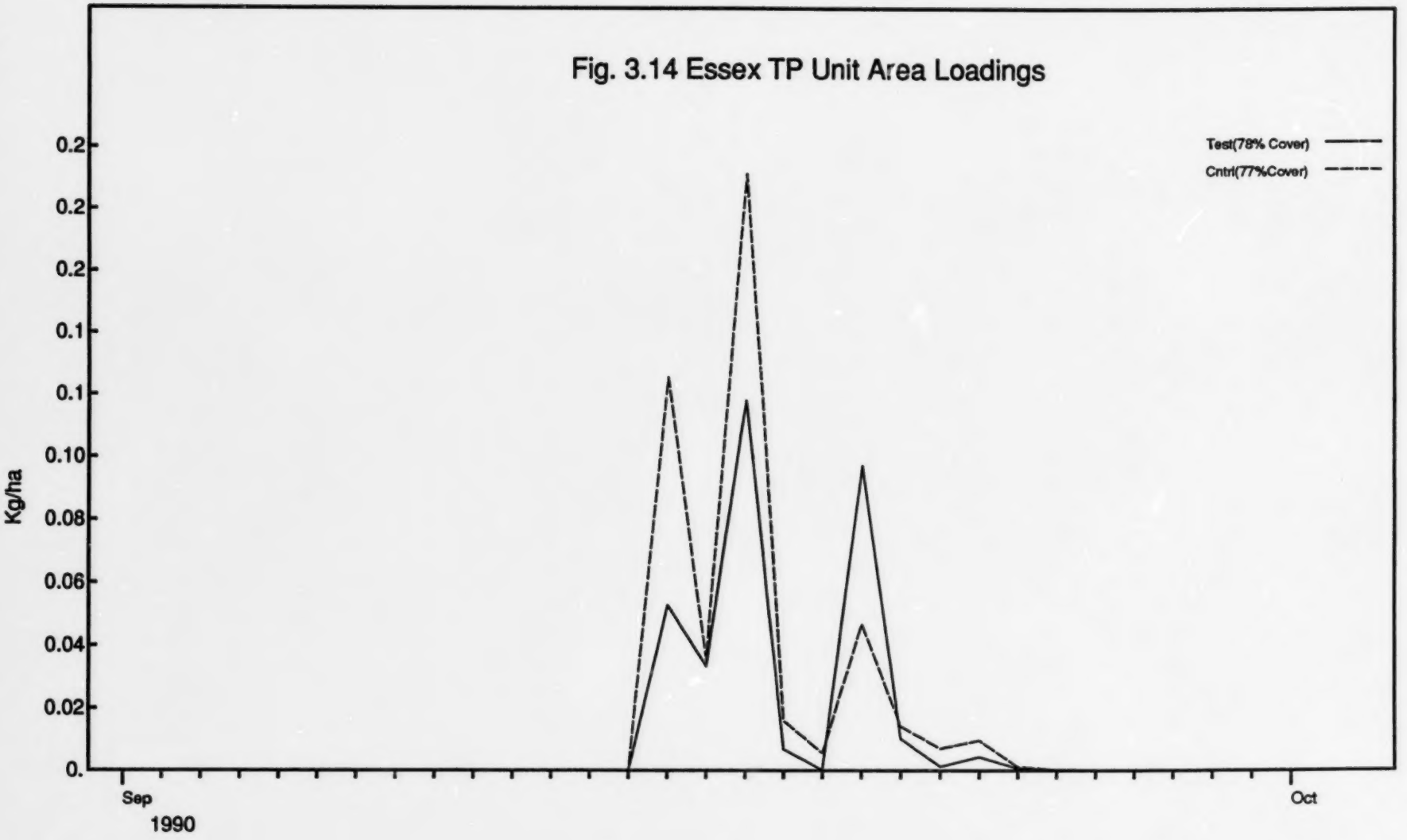
Fig. 3.14 Essex TP Unit Area Loadings
Test(78% Cover)
Cntrl(77%Cover)
Kg/ha
0.2
0.2
0.2
0.1
0.1
0.10
0.08
0.06
0.04
0.02
0.
Sep
1990
Oct

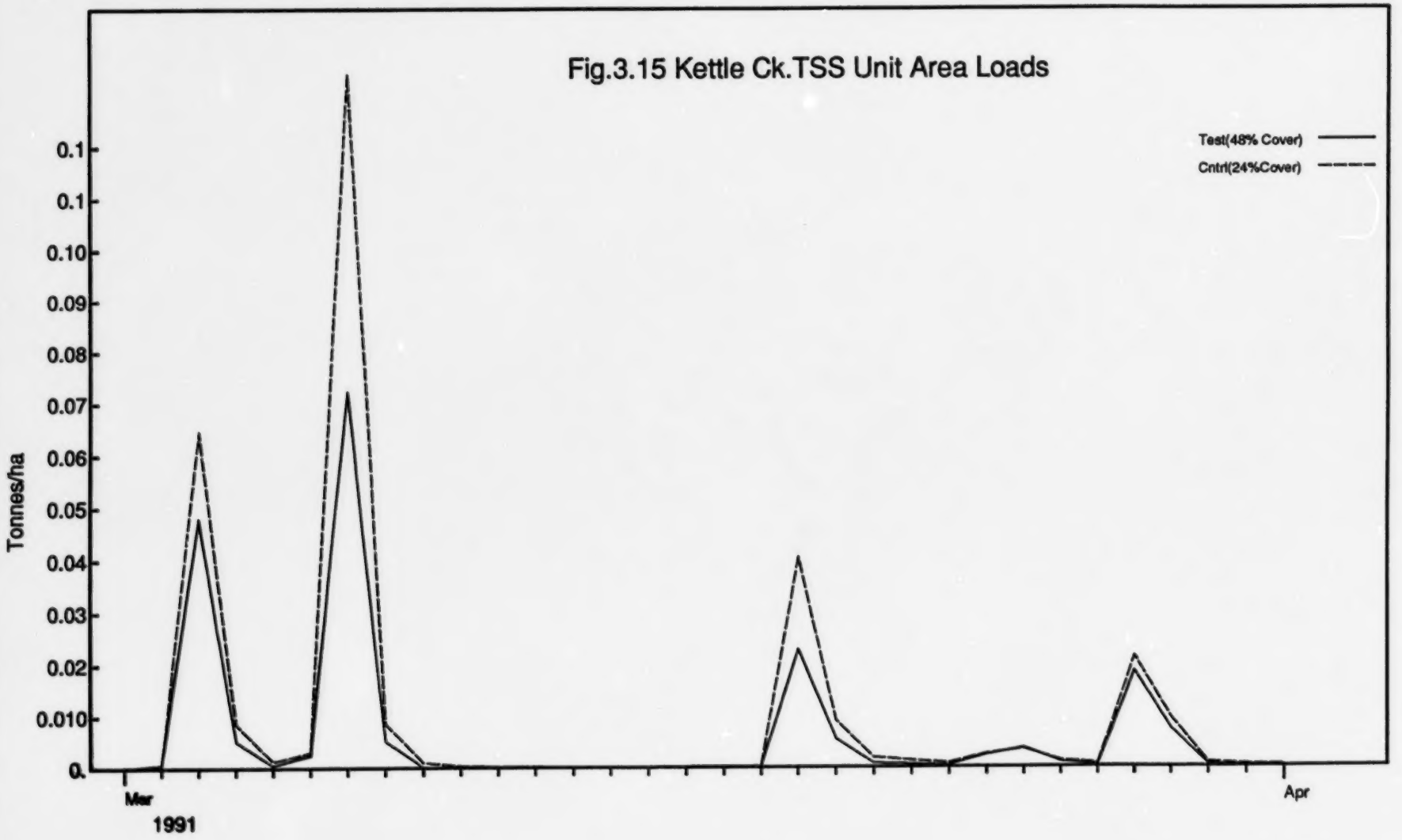
Fig.3.15 Kettle Ck.TSS Unit Area Loads
Test(48% Cover)
Cntrl(24%Cover)
Tonnes/ha
0.1
0.1
0.10
0.09
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.010
0.
Mar
1991
Apr

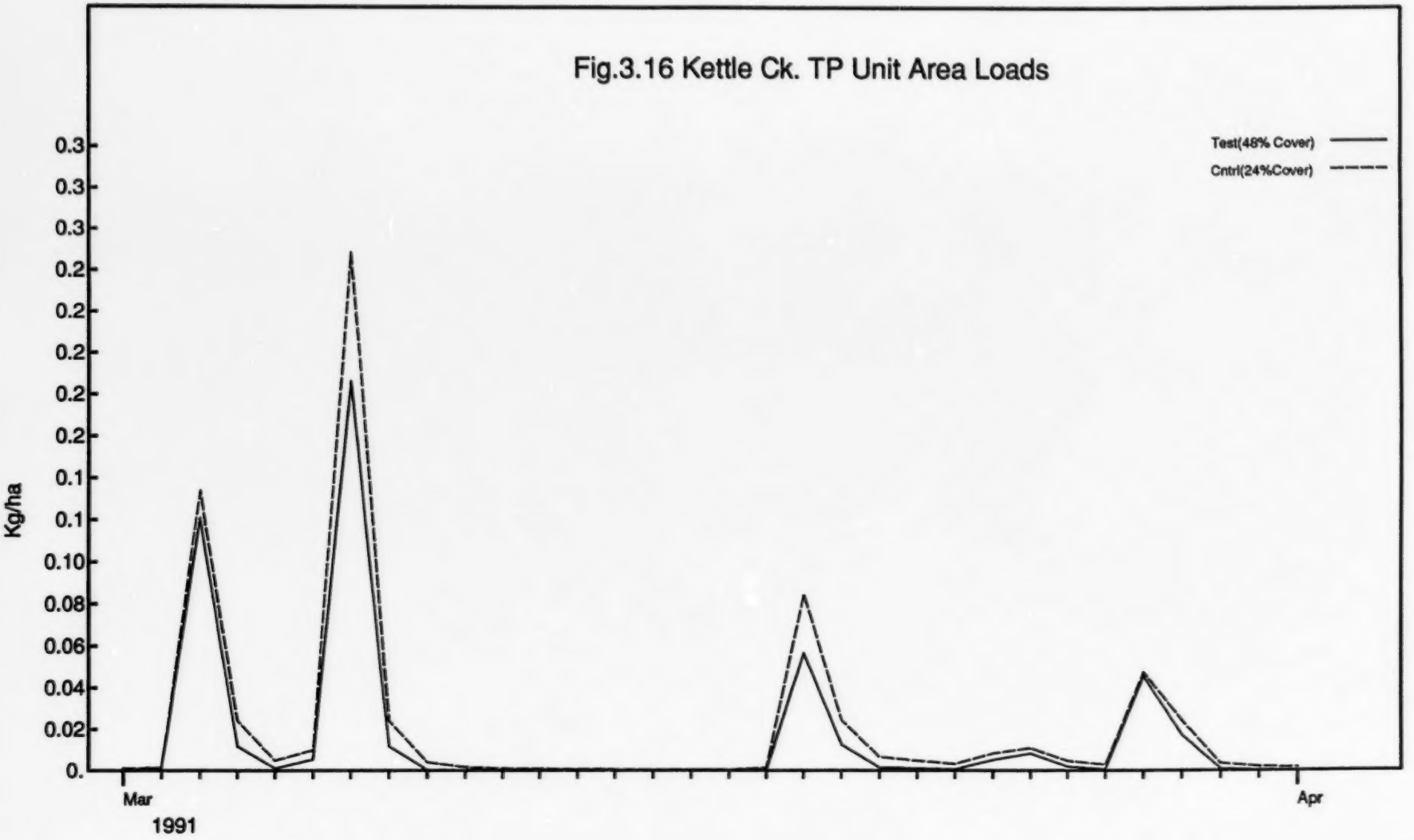
Fig.3.16 Kettle Ck. TP Unit Area Loads
Test(48% Cover)
Cntrl(24%Cover)
Kg/ha
0.3
0.3
0.3
0.2
0.2
0.2
0.2
0.2
0.1
0.1
0.10
0.08
0.06
0.04
0.02
0.
Mar
1991
Apr

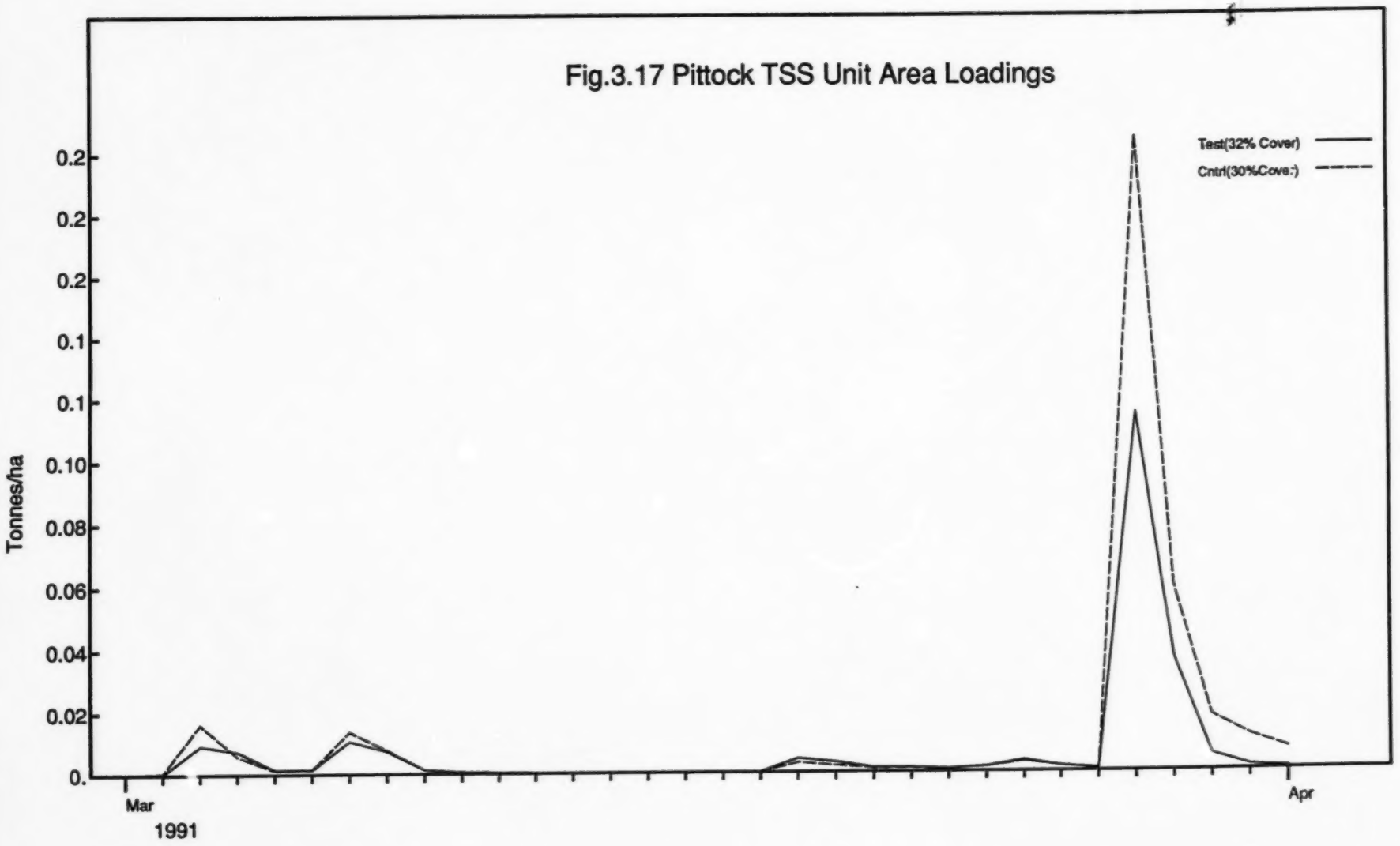
Fig.3.17 Pittock TSS Unit Area Loadings
Test(32% Cover)
Cntrl(30%Cove:)
Tonnes/ha
0.2
0.2
0.2
0.1
0.1
0.10
0.08
0.06
0.04
0.02
0.
Mar
1991
Apr

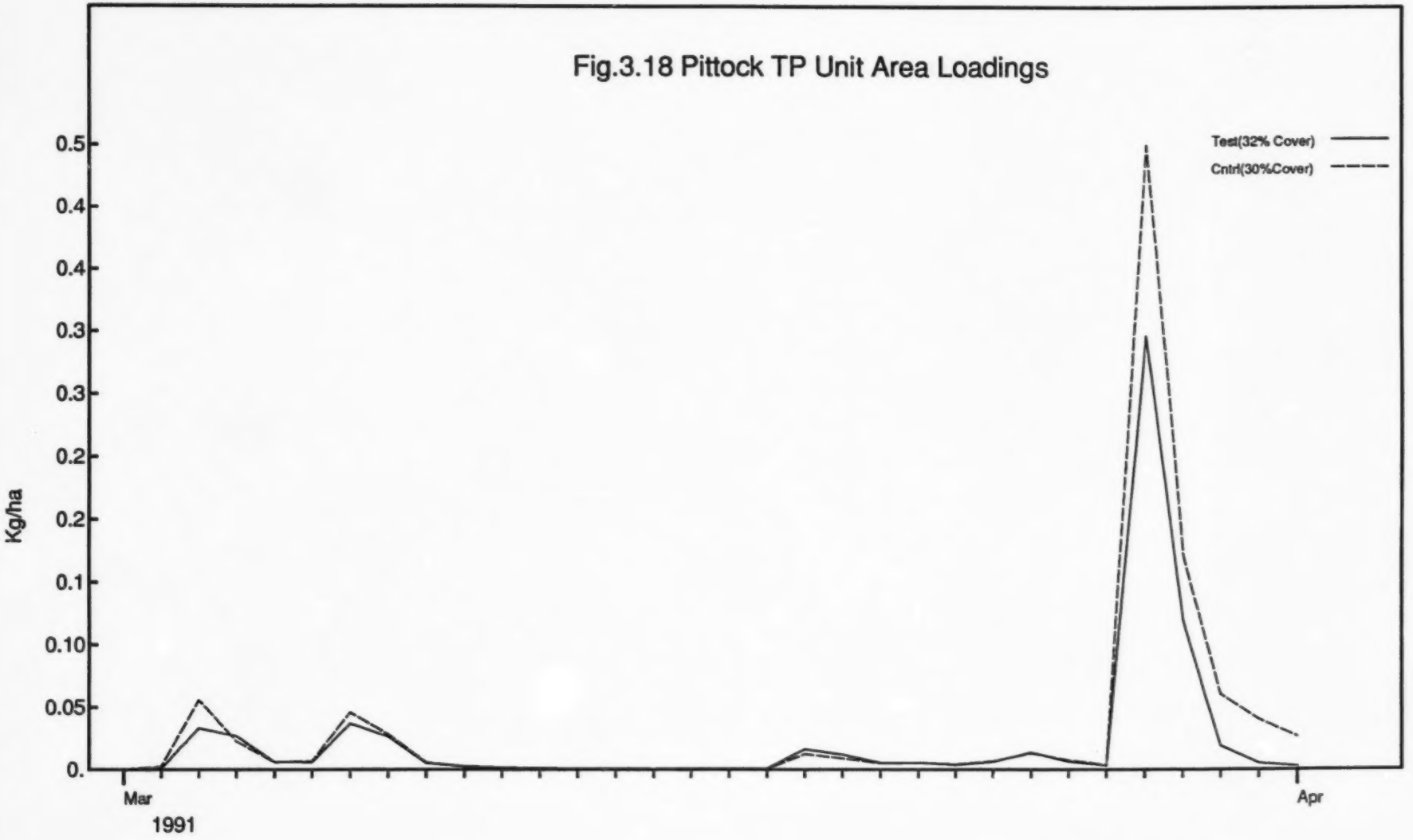
Fig.3.18 Pittock TP Unit Area Loadings
Test(32% Cover)
Cntrl(30%Cover)
0.5
0.4
0.4
0.3
0.3
0.2
0.2
0.1
0.10
0.05
0.
Kg/ha
Mar
1991
Apr

FIGURE 3.19: ESSEX MICROBASIN
TSS LOAD VS. FLOW

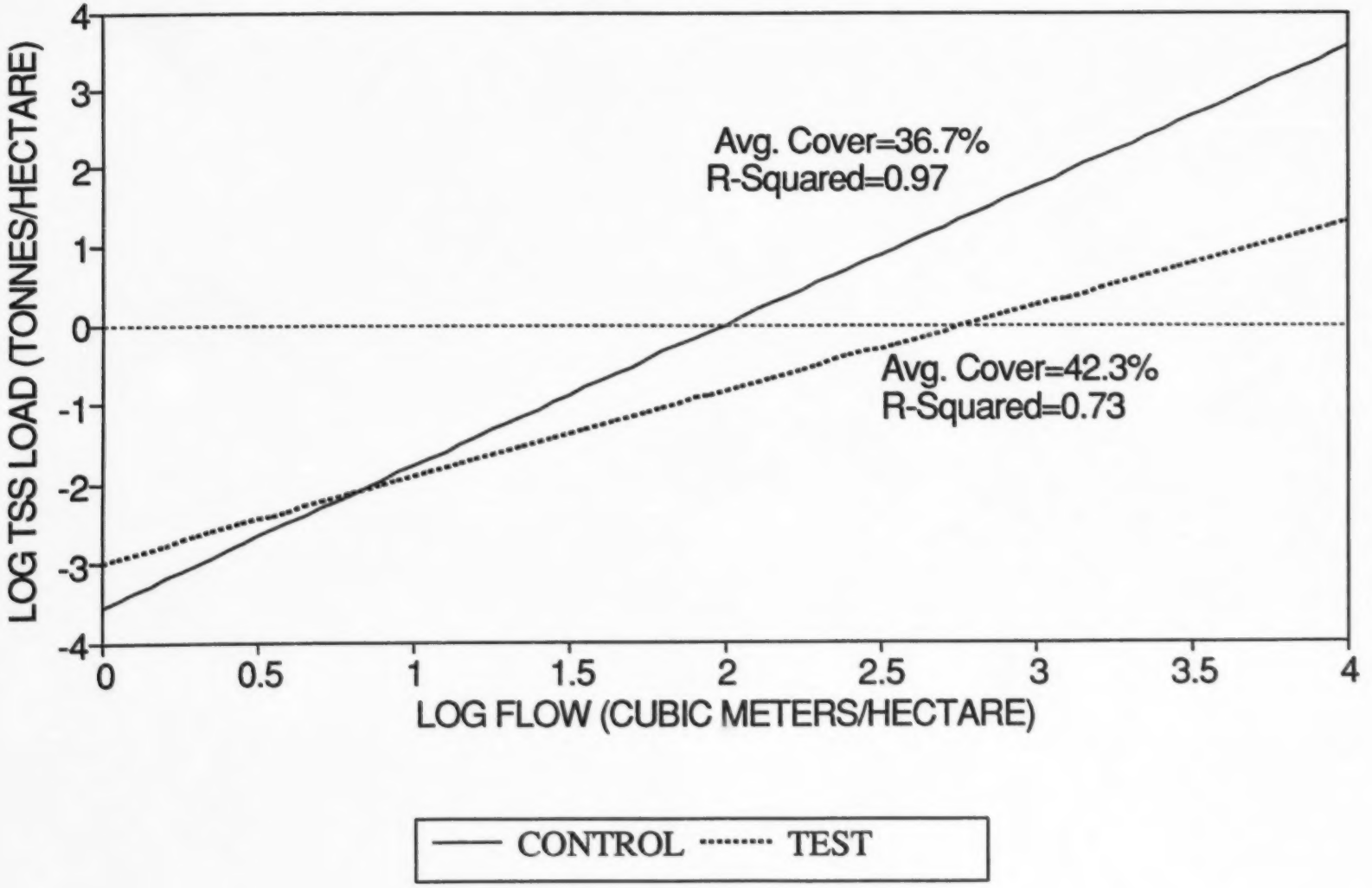

FIGURE 3.20: ESSEX MICROBASIN
TP LOAD VS.FLOW

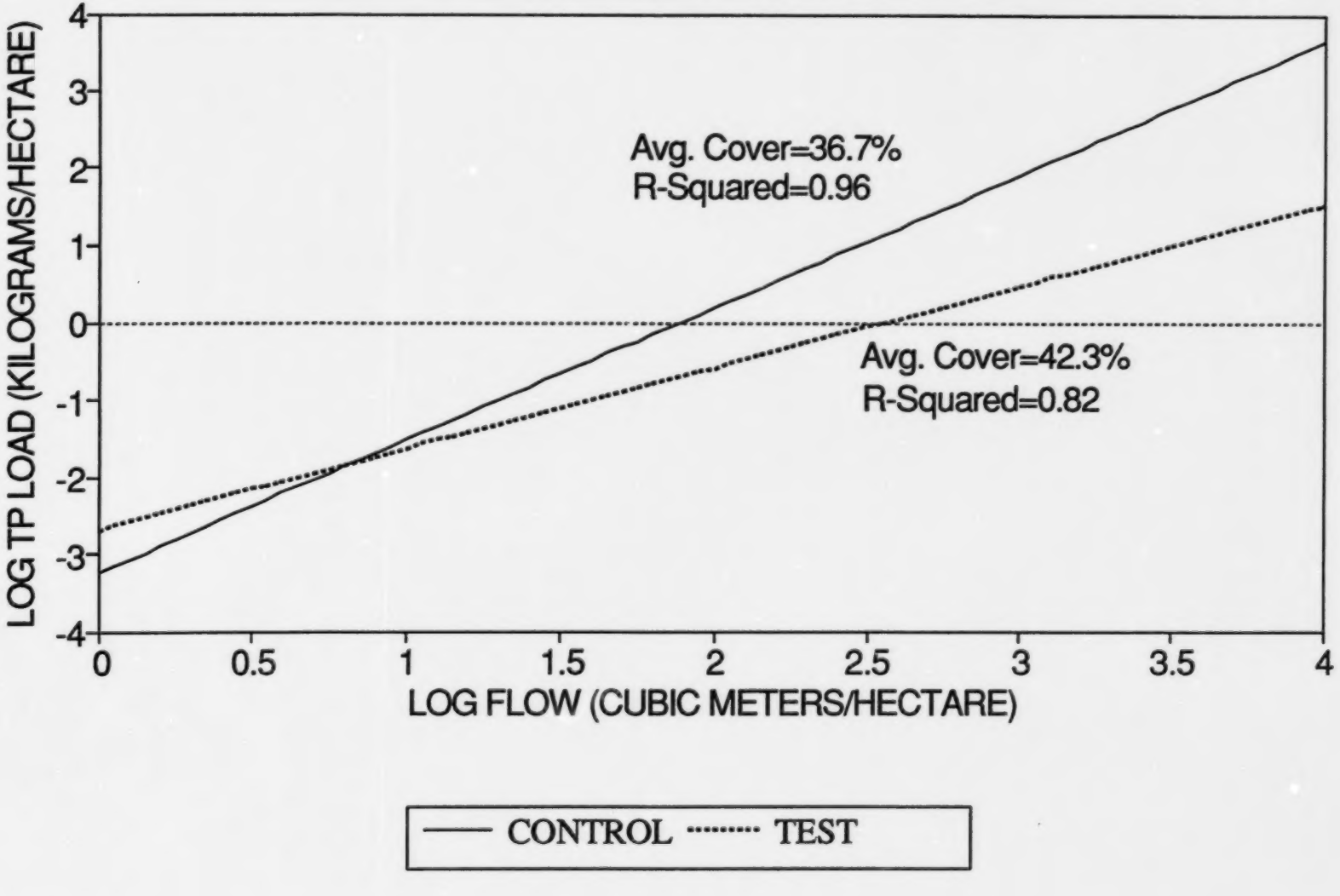

FIGURE 3.21: KETTLE CREEK MICROBASIN
TSS LOAD VS. FLOW

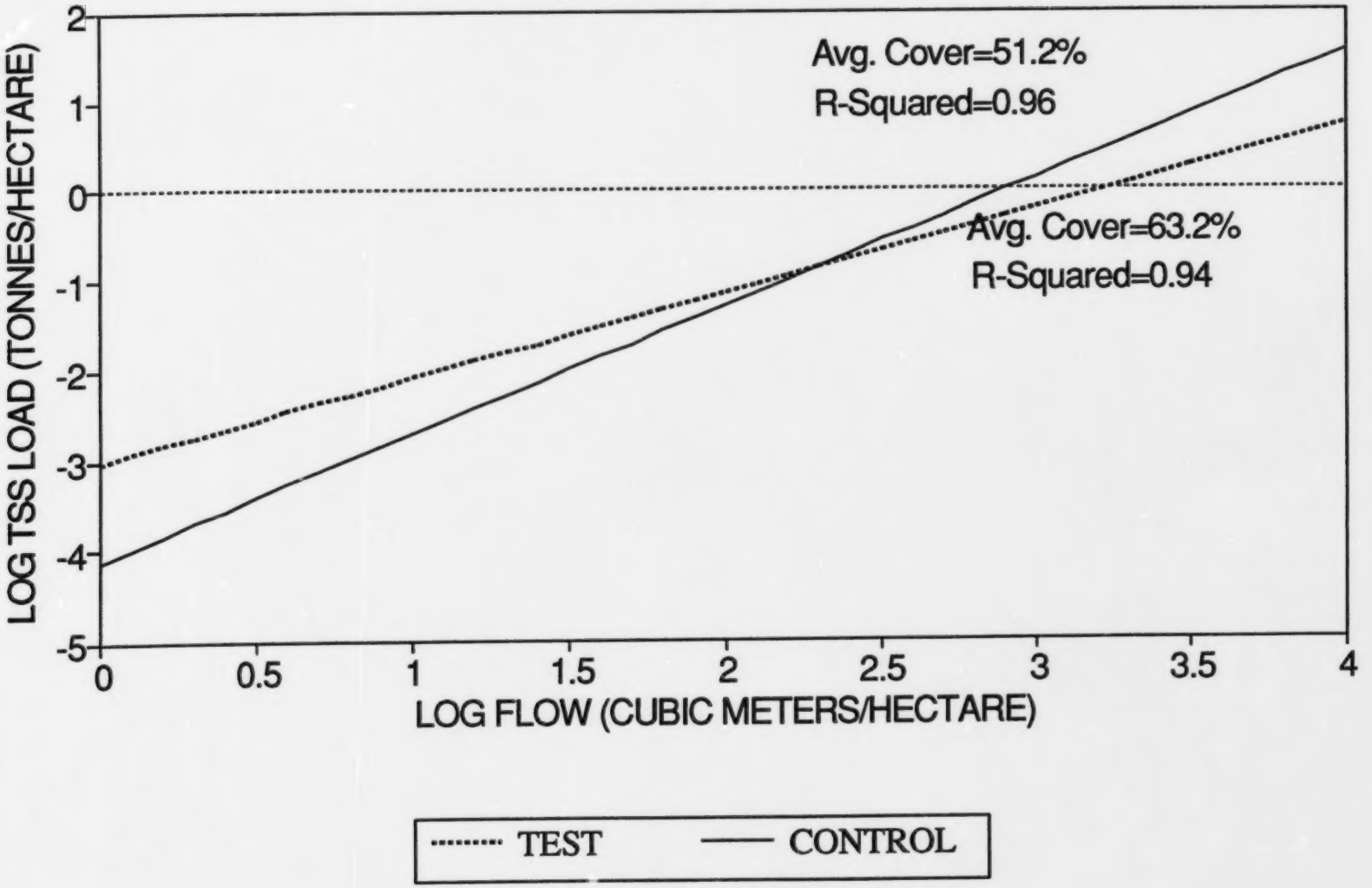

FIGURE 3.22: KETTLE CREEK MICROBASIN
TP LOAD VS. FLOW

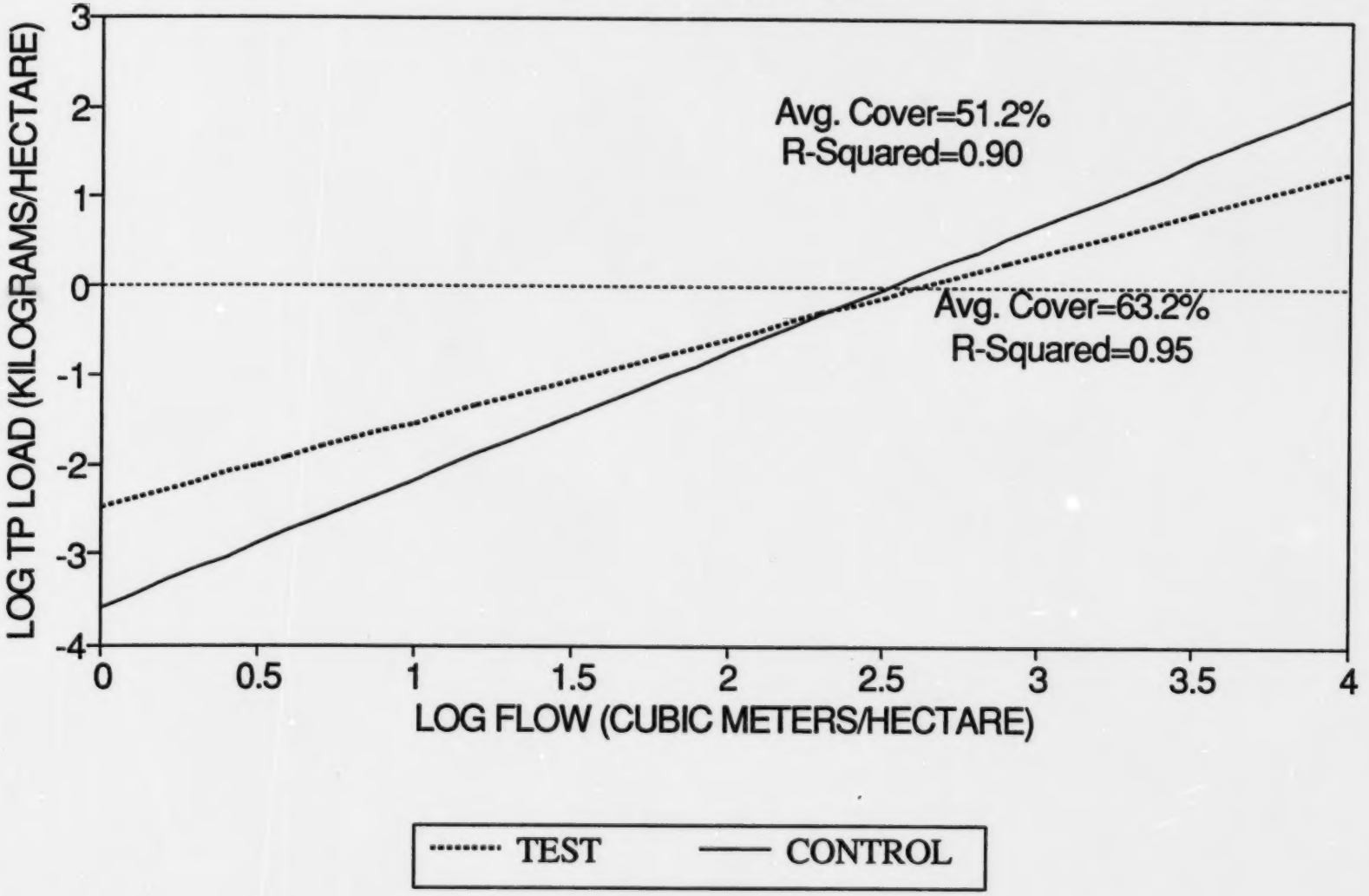

FIGURE 3.23:RAINFALL SIMULATION SUMMARY
TOTAL SUSPENDED SOLIDS

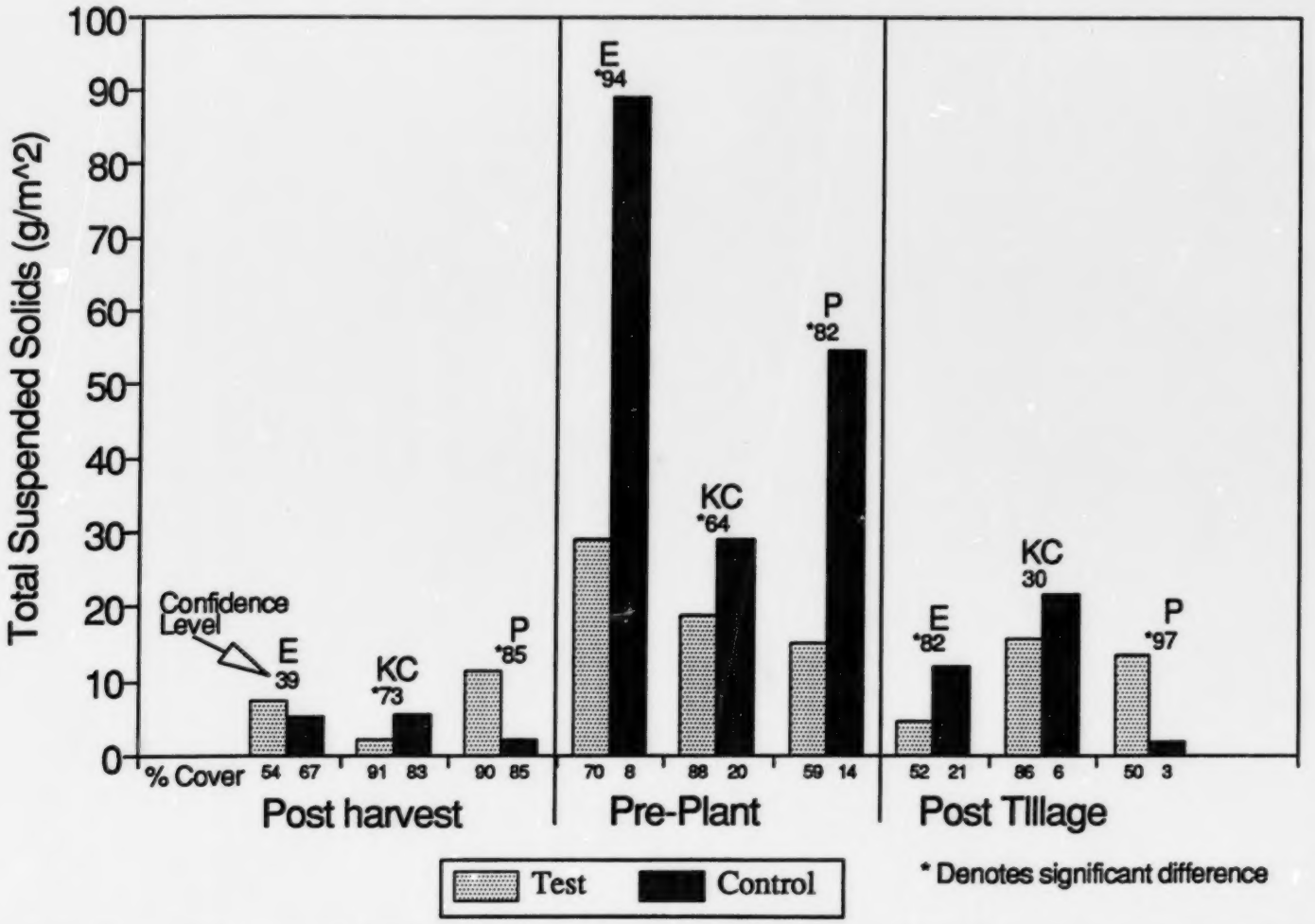

FIGURE 3.24:RAINFALL SIMULATION SUMMARY
TOTAL PHOSPHORUS